THESIS

DEVELOPING AND USING A PROFESSIONAL DEVELOPMENT MODEL FOR ENHANCING THAI ELEMENTARY SCIENCE TEACHER TEACHING: A REFLECTIVE, INQUIRY-BASED APPROACH

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The aim of this study was to investigate the effect of developing and using a reflective, inquiry-based professional development model that consisted of a three-day workshop and three months of sustained contact modified lesson study. This model was designed to serve Pathum Thani teachers' needs with respect to improving inquiry teaching, improving analysis of the core curriculum, writing lesson plans, and working collaboration in the school context. In this study, four teachers participated in a case study and provided insight into the effect of the reflective, inquiry-based professional development model on their understanding and practice of inquiry. This interpretive case study drew from data of questionnaires, interviews, journal entries, case reactions, classroom cases, metaphors, field notes, and teacher artifacts. Constant comparative method was used to analyze data. This involved coding, categorizing and comparing to develop emergent patterns of teacher change through the professional development.

The use of the reflective, inquiry-based professional development model effected changes in the four teachers' understanding, beliefs, and practice of inquiry. Inquiry opportunities involving the 5E learning cycle of engaging, exploring, explaining, extending/elaborating, and evaluating enhanced teachers' understanding of earth science concepts. The reflection on cases enhanced teachers abilities to construct and translate narrative understandings of inquiry into practice. Teachers' practice gradually changed reflect higher levels of inquiry. Teachers' beliefs about inquiry, as represented in their metaphors, changed from teacher-centered to more student-centered in nature; however, they still retained some beliefs about teacher-centered learning which constrained their full implement of inquiry.

The findings of this study suggest that the design of a reflective, inquiry-based professional development model helped teachers make positive changes needed to translate inquiry into their classroom practice. Elements of the model that supported this were integrating teachers' specific professional development needs; process and opportunity for inquiry learning; reflective experience in fostering knowledge of instruction; connecting theory to experience in their context; and team-building and facilitating along with opportunity for extending new ideas.

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CHAPTER I

INTRODUCTION

This chapter discusses the Thai educational context, rational for the study, outline of the study, purpose of the study, anticipated outcomes, delimitation of the study, subjectivity and personal bias, salient terms important to this study. The last section is a summary of the chapter and preview.

Thai Educational Context

1. Thai Educational Reform: The Historical Context

There are four major periods of Thai educational reform (Fry, 2002; Office of the National Education Commission [ONEC], 2005). In the history of Thai education, most reforms that occur stem from the changes in culture and politics. In prior reform eras dating back centuries, Thai education focused almost solely on young men. Traditionally, the system of education in ancient Thailand (Siam) was found in Buddhist monasteries. Monk learning created an important traditional system of education (ONEC, 2005), which had a lasting impact on Thai culture and society.

According to ONEC (2005), the first formal educational reform took place during the period of King Chulalongkorn (1868-1910). King Chulalongkorn had a visionary leadership aimed at transforming Siam from a traditional into a modernizing society. This reform in Siam also included Thai education. The first educational reform was initiated because of: (a) threats from western imperialism, (b) King Chulalongkorn's experience in education from western countries, and (c) the lack of quality authority.

In the year of 1932, Thailand changed into a form of democracy in which the king is still the leader of the country. In the period of 1973-1980, the National Scheme of Education encompassed three five-year educational development plans: the Fourth, the Fifth, and the Sixth National Education Development Plans. With each of these plans, the policy agenda gradually widened its scope to address issues of poverty and inequality. Educational policies were introduced to increase rural access to schooling, improve the administrative system, and strengthen curricula and the learning process. Priority was given to issues of quality in education. In addition, science, technology, and non-formal education were strongly emphasized and the role of private education was encouraged. Subsequently, the Seventh National Education Development Plan (1992-1996) aimed to provide a balance between all aspects of economic, social and cultural development. It was also designed to facilitate linkages between these aspects and to create harmony and mutual benefit between urban and rural sectors (Department of Curriculum and Instruction Development, 2001).

As noted above, Thailand has undergone many reforms and changes in the nature of education. The latest change in Thai Education is the new education reform of 1999, part of the Eighth National Education Development Plan (1997-2001). The recent changes in the National Education Development Plan (ONEC, 2005) in Thailand reflect the history of elementary education reform in the following ways:

1.1 The First Thai Educational Reform (1868-1910): The Visionary Reforms of King Chulalongkorn (King Rama V)

The educational policy of King Chulalongkorn focused on expanding education for all Thais. He held the view that education was important for developing a modern country. He supported the notion of compulsory education (elementary grades 1-7). Moreover, he also encouraged higher education at the secondary level (grades 1-8). This system was established and prevailed for a long time in the history of Thai education (ONEC, 2005).

1.2 The Second Thai Educational Reform (1973-1980): The Revolution of Thai Education in Democracy

Thailand became a “democracy” in the year of 1932. During this period the Thai education system was still the same until the beginning of the second educational reform period in 1973-1980 (Fry, 2002). In the second reform period, Thai students put their lives on the line to create a more democratic plan to serve the emerging Thai democratic society (Fry, 2002). The Fourth National Education Development Plan (1977-1981) emphasized the acquisition of basic knowledge and skills in elementary learners. This plan placed an emphasis on education for literacy in reading, writing, and mathematics. The plan also emphasized the development of learners who would be able to earn a living appropriately for age and ability and perform the role of good citizens. In this plan, student learning at the elementary level encompassed a period of six years (ONEC, 2005).

1.3 The Third Thai Educational Reform (1990-1995): The Challenges for Globalization

During the period of the third educational reform, the economy at this time needed to change in accordance with the rapid economic growth of South East Asia. Therefore, the attempt at educational reform emphasized Thailand's need to adapt to the challenge's of globalization and internationalization such that the country would have a major impact in the economic landscape of the region (Fry, 2002).

When the Seventh National Education Development Plan was revised in 1992-1996, Thailand was experiencing many rapid changes both academically and in terms of communication technologies. Changes in the communication network affected both individual and social life. However, problems arose as people found it difficult to adapt to these changes. Consequently many unbalances in society emerged, including problems with citizens' physical and mental development, the utilization and conservation of natural resources, the declination of the environment, the neglect of Thai wisdom and the lack of co-operation among community members (ONEC, 2005). The government realized that it was not solely responsible for meeting the educational needs of development in individual local communities throughout the country. Therefore it became necessary to revise education in terms of principle, aim, policy and guidelines to help Thai citizens develop lifestyles that were appropriate for the societal context. The Seventh National Education Development Plan focused on four aspects: intelligence, mind, body, and social development. The guidelines for elementary education in this period aimed to develop learners in terms of morality, content knowledge, language and mathematics literacy (ONEC, 2005).

1.4 The Forth Thai Educational Reform (1997-present): Crisis as Opportunity

Thailand's current educational reform initiatives stem from the shock of the Asian economic crisis. In order to stimulate economic recovery, new educational reform is urgently needed (Fry, 2002). The new era of national education in Thailand started with the implementation of the revised constitution in October 1997 (Department of Curriculum and Instruction Development, 2001). Urgent steps were taken by those concerned to make preparations for the enactment of the National Education Act 1999 in accordance with the Eighth National Education Development Plan (1997-2001) of Thailand. There were many requirements to address in the various provisions, especially with respect to the universalization of the 12 year basic education. In spite of the permanence of many of the above developments, Thailand still lacked the equilibrium needed to address societal issues. According to ONEC (2005), some of the lingering problems included:

- Unemployment, poverty, crime, and family problems

- Disadvantage in economic competition with other countries

- Extreme declination of the environment

- Lower quality of education

- Lack of unity in policy of education, lack of flexibility for school administration, lack of co-operation among people, communication and social institutions

- Less realization of Thai-ness and Thai culture

- Neglect of Thai wisdom

- Less acceptance of religious institutions

Because of the persistent nature of these problems, the government decided to develop a new vision and policy to help develop Thailand in ways that emphasize equilibrium with respect to the development of the economy, society, humanity and nature under Thai culture and religion.

The study of ONEC on educational reforms in 12 countries including the United States of America, England, France, Australia, New Zealand, Korea, Japan, Vietnam, Malaysia, China, Laos, and Hong Kong (Roonchareon, 2002.) The results of this study showed that successful educational reform in these countries was comprised of a) a focus on learner quality, b) the construction of laws to support education reform, c) the role of leaders in education reform, and d) collaboration from all citizens.

In order to work towards similar success in Thai education, every section of the National Education Act B.E. 2542 (1999) and Amendments (ONEC, 2002) promotes the educational principles of “student centered curricular approaches.” The basic principle of the new Thai education reform is education for Thai people, with a focus on body, mind, intelligence, knowledge, morality, ethics, culture of living, and living in harmony with others. Moreover the National Education Act B.E. 2542 (1999) also contains three principles to guide education including life-long learning, education for all and all for education, and the simultaneous and continuous development of context and learning processes.

Conclusion of Thai Educational Reform

Across the history of Thai educational reform, politics and culture are the main factors that fostered educational change. In the first reform period, King Culalongkorn focused on modernization the way of life. The education reform in this period was intended to prepare Thais to overcome the crisis of Western imperialism by creating a modern and independent Thailand. The second period of Thai educational reform focused on preparing people to support new the democratic society. The need for the country to play an important role in the economic landscape of South East Asia region led to the forth reform of Thai education. Thai people were prepared to help the country develop in the international arena. In the current fourth reform, the challenge is to ensure that all Thai children have the opportunity to realize their full potential and creativity. Children as the future of the country are viewed as the persons who can develop and lead the country in the right way.

2. The Status of Elementary Curricula in Thai Educational Reforms

2.1 Elementary Curricula before Education Reform in 1999

In 1991, the structure of elementary curricula (Department of Curriculum and Instruction Development, 2001) did not consist of individual fragmented courses; rather, it was comprised of five learning experience groupings as follows;

- Basic Skills Group, comprising Thai language and mathematics as the tools for learning subjects;

- Life Experiences, dealing with the processes of solving social and daily life problems, with an emphasis on scientific process skills for better living;

- Character Development, dealing with activities necessary for developing desirable habits, values, attitudes and behaviors, which should ultimately lead to a desirable character;

- Work-Oriented Experiences, dealing with general practical work experiences and basic knowledge for career preparation;

- Special Experience, dealing with activities based on learners' interests provided for those in grades 5-6 only. The learning activities in the area of special experiences can be organized by each school according to learners' needs and interests and may include knowledge and skills selected from the other four groups such as English for everyday life.

Science for elementary levels was included in the learning experience that is described as “Life Experience”. The elementary curricula B.E. 2521 (1978) which had been revised in 1990 had the following purposes (Department of Curriculum and Instruction Development, 2001):

- Teaching should be flexible and correspond with local events; local educational personnel should develop the curriculum and instructional media.

- Teaching should emphasize student centered approaches, in accordance with learners’ interests and real life situations, and should provide an equal chance for all to develop their full potential.

- Teaching should connect and integrate with learning experience groups.

Even though the elementary curricula had a revised version, it was not much success in emphasizing student centered approach. Elementary teachers also found problems in learning organization such as curriculum analysis, lesson plan design, create and prepare learning material, create and implement assessment tools (Kwanton, 1998). These were big challenge on changing the organizing learning and assessment in the new education reform.

2.2 Elementary Curricula in Present Times

To implement principles, goals and learning standards at educational institutions, and for those concerned with the formulation of educational institution curricula, the structure of the basic education curricula is now organized into four grade levels in accordance with developmental theories. The first level for grades 1-3 is designated lower- elementary, the second level for grade 4-6 is designated upper-elementary, the third level for grade 1-3 is designated lower-secondary, and the fourth level for grade 4-6 is designated upper-secondary (Department of Curriculum and

Instruction Development, 2001). The elementary curriculum consists of a body of knowledge, skills or learning processes, values or virtues, morality and appropriate behavior. This curriculum is organized into eight categories that are Thai language, mathematics, science, social studies, religion and culture, health and physical education, art, career and technology, and foreign languages. These categories are considered fundamental areas of learning required for all students. The first and the second level, primary grades 1-3 and 4-6 are the first stages of compulsory education. The curricula focuses on learning quality of life, social studies processes, basic skills in reading, writing, mathematics, critical thinking, communication, and the foundations of humanities. Emphasis is placed on a well balanced integration of physical, intellectual, emotional, and social development and Thai culture.

The Office for National Education Standards and Quality Assessment (2004) constructed the standards for basic education as a framework to guide external and internal evaluation. Moreover they are also intended to be used as a guideline for institutional development, in a similar way. The Standards for Basic Education consist of four main groups as illustrated below;

2.2.1 Learner Standards: Emphasis on development of body, mind, intelligence and learners as good, competent, and happy individuals. A good, competent, and happy learner is defined as one who holds the following characteristics:

A. Competent: Thai knowledge, international knowledge, comprehension, specialization, creative thinking, leadership skills, modernization, inquiry, life long learning

B. Good: Quality in conducting ones' life, good mind and behavior, morality and ethics, self and social discipline, democracy, self control, development of full potential, and working for collective benefit

C. Happy: Healthy, vivid, strong heart, happy in learning and working, love for everything, friendly, no drugs, living cooperatively with others

2.2.2 Process Standards: Emphasis on the process of administration and the process of teaching and learning

A. Factor Standards: emphasis on the characteristics and readiness of school administrators, teachers, curricula, schools, and communities (Roonchareon, 2002)

B. Learning Community Standards: emphasis on development of using learning resources and local wisdom and collaborative between school and local organization in developing learning community.

In order to prepare schools for the new reforms, the Institute of National Elementary Commission evaluated the standards of learner, process and quality control factor in schools (Roonchareon, 2002). Many schools in this study were evaluated at each site; 21,491 schools were evaluated with respect to quality of the students; 21,925 schools for quality of school administration; 21,925 schools with respect to the teaching and learning process, and 16,513 schools in terms of quality control within schools. The results of this study indicate that:

- Almost all elementary schools failed the criteria associated with quality of the students and the teaching and learning process

- Problems related to administration and the teaching process were widespread. The problems identified were: (a) lack of teachers and especially teachers with sufficient knowledge of the curriculum; (b) teacher resistance to changing traditional teaching behaviors; (c) teachers' lack of understanding about how to teach using student centered approaches; (d) teachers' lack of voice in creating the local curriculum; (e) teachers not following the conventions of professional development

Although Thai education is undergoing the process of reform, the results from this survey show that there is still much to be done in terms of the readiness of educational administration and quality of the teaching and learning process. The outstanding obstacle appears to be the lack of adequate preparation of teachers. Teachers play an important role in the teaching and learning process, according to the guideline of the National Education Act 1999, and need to help the learner develop to his/her fullest potential and assist them in becoming competent, good, and happy individuals. Therefore new innovations in teacher development and preparation are needed to prepare individuals in this 21st century era of educational reform.

3. Professional Development in Thailand

At present, there is a strong need for well prepared science teachers. Research shows that in Thailand, teacher preparation needs improvement in terms of both quantity and quality (Human Resource Development Association, 1997). In addition to the extension of basic education from grade six to grade nine and the revision of the structure of science curriculum at the elementary level, there has been a tendency to separate the science substance from the learning of “Life Experience.” Therefore it is necessary for both prospective and practicing science teachers to have science content and pedagogical knowledge and experience in science teaching in order to prepare activities that emphasize science processes, science attitudes, morals, and ethics that are suitable for the present Thai society.

3.1 The Problems of Traditional Professional Development

Traditionally, the Ministry of Education assigned the responsibility for professional development in science teaching at the school level to the Institute for Promotion of Teaching Science and Technology (IPST). Moreover, the ministry also collaborated with the Office of Rajabhat Institute Council, Department of General Education, Department of Vocational Education, Rajamangala University of Technology, Office of the Private Education Commission, Office of the National Primary Education, Ministry of Education, Bangkok Education Institute, and the Local Education Institute (IPST, 2002) to design the professional development plan for the budget years 1996-2001. The goal was to develop a project aimed at producing core-instructors who could serve as leaders for preparing science education professional development in local settings. These core-instructors were trained by IPST, and were to share their knowledge of science teaching and learning in their local settings.

The core-instructors were selected from a pool of science teachers in schools all around Thailand. The instructors of project were from science education supervisors at the following institutes: Rajabhat Institute, Rajamongkol Technology Institute, Department of General Education, Office of the Private Education Commission, Bangkok Education Institute, and the Local Education Institute. This project focused its professional development goals on both the quantity and quality of science teachers in the project. It was a big project expected to train about 3,533 core-instructors and 243,508 teachers within five years. The program evaluation report for the first half period of the project (Educational Supervisor, 1992) showed the advantages and disadvantages of the project as follows:

The advantages of this project consisted of

- School community could construct their own professional development that could support the school needs

- The core-instructors were mostly in their own local settings; therefore they could design the training for their own school

- The core-instructors could guide the professional development consistently in terms of project goals

- There was collaborative work among the school community, educational supervisors, and core-instructors

The disadvantages of this project consisted of

- There were too many trainees, so it was difficult to implement in practice

- The prior background knowledge of each trainee was not equal
- Some activities did not support the trainee needs

- Because of the long-term nature of this professional development, there were too many changes in administrators and control of professional development standards and professional development evaluation.

3.2 The Purpose of Professional Development in Thailand in the Current Era of Reform

The National Education Act B.E. 2542 (1999) and Amendments in chapter 7 (ONEC, 2002: 22) states that "the ministry shall, in this regard, take a supervisory and co-coordinating role so that the institutions responsible for production and development of teachers, faculty staff, and educational personnel shall be ready and capable of preparing new staff and continually developing in-service personnel." Professional development is necessary for Thai teachers, especially for primary science teachers who face problems with science and pedagogical understandings of new curricula. Because of the rearrangement of the new science curriculum from a "Learning Experience" which integrates Health and Society into "Science Substance," which aims to engage students in more science skills by emphasizing student centered approaches, many teachers need more knowledge of student centered science teaching and learning. The Office of the National Education and Rajabhat Suan Dusit Instutute (ONEC, 1999) surveyed the opinions of school administrators and teachers in grade 1-9 from 729 schools about "the readiness for student centered instruction". The results showed that most teachers (44.9 percent) had an average level of knowledge about student centered-teaching. Moreover 41.0 percent of the teachers agreed that there is an urgent need for professional development in student-centered teaching; another 37.8 percent of teachers strongly agreed about the need for professional development in student-centered teaching.

Today, education in Thailand is in the process of new reform. The National Education Act B.E. 2542 (1999) and Amendments (ONEC, 2002) is the guideline that the stakeholders involved in education use as a guide and follow in order to develop a Thai Education of high quality. Moreover, there are many published documents aiming to provide standards for developing many aspects of the Thai educational system. Development of education in all areas, including professional development, is reflecting a new vision of professional growth that differs from the traditional top-down approach. This new vision advocates the need for educational personnel who can take ownership for their own development. Therefore, alternative professional development models are needed to assist teachers in becoming self-regulated, reflective learners.

Rationale for the Study

1. The Need for Enhanced Professional Development in Earth Science

Earth science content is an important part of the new science curriculum of Thailand. It is found in the sixth science strand under the name “Processes that Shape the Earth.” In 1999, the Basic Science Curriculum (IPST, 2003) was released in response to the new education reforms of the National Education Act B.E. 2542 (1999) of Thailand. The “Processes that Shape the Earth” theme, although presenting in the old curriculum, did not originally have much earth science content. One difference in the earth science content between the old and new curricula is the added shift to more depth in geology and meteorology. Secondly, in the new curricula, the contents are realigned in terms of basic to advance concepts. Processes that Shape the Earth starts with the topics of “local soil”, “local water resources”, and “the air around us” in the first level (grade 1-3), “local rocks and their transformation”, “soil formation”, “weather condition”, “phenomena of climates”, and “water cycles” in the second level (grade 4-6) and “meteorological phenomena”, “changes of the earth’s temperature”, “soil, rock, and minerals”, “surface and underground water”, “the process of the geological transformation”, and “components of the earth” in the third level (grade 7-9). Lastly, the teaching of earth science now places more emphasis on student-centered approaches. In light of these changes, the challenge for teachers is to create activities that support student knowledge construction of earth science (IPST, 2003). Teachers need to have their own experiences by doing. Moreover they need meaningful learning that requires the active construction of an integrated network of related ideas rather than the memorization of isolated facts (Shymansky *et al.*, 1993). For this reason, many organizations in Thailand have initiated efforts to improve earth science teaching and learning. The GLOBE Program in Thailand (IPST, 2004) and LESA Project (TRF and Kirdkao, 2004) are two examples. These projects were developed to facilitate teachers' learning with respect to earth science. Because the teaching of earth science is now more advanced, both in terms of content and strategies, there is an urgent need to develop meaningful professional development experiences in Earth Science.

Even though many organizations, both internationally and in Thailand (for example, the Institute for Promotion of Teaching Science and Technology [IPST] and the Thailand Research Fund [TFR]) have tried to develop the teaching of Earth science in Thailand, there are difficulties which obstruct the full implementation. For example, many international studies (Aron *et al*., 1994; Bar and Travis, 1991; Doran, 1972; Dove, 1998; Nelson *et al.*, 1992; Philips, 1991; and Stepans and Kuehn, 1995) confirmed that students have knowledge about weather and the atmosphere which is different from that of scientists. Students often bring these alternative conceptions to the classroom. Besides students' alternative conceptions regarding weather and the atmosphere, research showed that pre-service teachers have alternative conceptions in meteorology surrounding concepts such as the causes of seasons (Atwood and Atwood, 1996). The current situation with elementary teachers' understanding in earth science content is reflected in a survey that was administered to 88 teachers during August-November in 2005 (Soparat *et al.,* 2007). The questionnaire sought the opinion of elementary teachers about their understanding in science contents which covered all science content of IPST's curriculum. The results indicated teachers have moderate understanding of many science topics, including earth science content. In addition, they also referred on their students who have weak understanding on those science contents. Therefore it stands to reason that students' alternative conceptions may sometimes stemmed from teachers who do not hold strong conceptions.

Didactic teaching strategies, which do not take into account students' knowledge and experience, and teachers' lack of earth science content knowledge have both presented challenges for teaching and learning earth science effectively.

King (2000), in a survey of earth science teachers, found that the majority had little background knowledge or practical experience with investigations or fieldwork in earth science courses. Moreover King found that teachers typically taught by textbooks and rarely prepared special earth science teaching materials.

Conclusion of the Need for Enhanced Professional Development in Earth Science

The challenges in earth science teaching are interesting and serve as the inspiration for this study. Teachers who want to develop themselves in teaching earth science need opportunities to participate in meaningful professional development designed to enhance teacher knowledge both their content, pedagogy and growth as reflective practitioners. Science teachers need to gain a firm understanding of the concepts involved, relate them to appropriate teaching strategies and understand their application in specific instructional contexts. In essence, teacher education and professional development needs to support teachers' development of conceptual and pedagogical understandings and their ability to enact these in diverse educational settings.

2. The Need for Inquiry-based Professional Development

Before the period of education reform in Thailand, 1999, most teachers taught with an emphasis on content rather than the processes of science and with a focus on memorization rather than critical thinking (Keawdang, 1998; Cheangkool, 1999). These traditional teaching approaches were not useful in helping Thai students develop in critical thinking or in the ability to communicate their thoughts (Keawdang, 1998). The evidence of low achievement in science was present in Thailand's National Test in every subject. This test is taken by students at the end of each level (grade 3, grade 6, grade 9 and grade 12). The results of Thailand's National Test in Academic year 2003 and 2004 revealed that the average score in the science subjects on the General Achievement Test (GAT) of grade 6 students in Pathum Thani province reflected a low average score in terms of both knowledge achievement and skill achievement (Pathum Thani Educational Service Area Office 1, 2003; 2004). Because of these results, educators in Pathum Thani province had focused on professional development to promote teaching and learning.

According to the National Education Act B.E. 2542 (1999) and Amendments (ONEC, 2002) , basic education based on the instruction that develops individuals as learners. Therefore all students should be able to think, make decisions, practice, make conclusions and construct their own knowledge. For science education, teachers in Thailand need the ability to create classroom environments that support this vision of Thai educational reform. Inquiry-based instruction is recommended as an effective way of teaching science. The Institute for Promotion of Teaching Science and Technology (IPST, 2003) suggests that science teachers should use inquiry to support students' learning in science.

2.1 Making Sense of Inquiry

Inquiry is a term used to describe both teaching and doing science (Reed, *et al.,* 2004). In term of teaching, inquiry is a particular method of teaching. It is an approach to teaching and learning which is based on sound and established concepts, and is directed toward achievement in content areas as well as toward development of rational powers (Bibens, 2001).

The Institute for Promotion of Teaching Science and Technology (IPST, 2003) of Thailand defined the meaning of scientific inquiry as the seeking of scientific knowledge through scientific process or other methods such as investigation, observation, measurement, classification, experimentation, and modeling. Moreover, inquiry as defined by the National Science Education Standards (NRC, 1996) and the American Association for the Advancement of Science (AAAS, 1993) had a similar meaning. Students themselves participate in scientific investigations that is focused on questioning about things to investigate and designing apparatus to see data to collect, and how to organize the data. The NRC (1996: 23) noted the dichotomy of teaching and doing science:

> …Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world

There are many levels of inquiry instruction which rely on the degree of independence with which students participate and interact in classroom. The levels of inquiry can be ordered from the lowest to the highest (Colburn, 2000; Windschitl, 2002) as follows;

- Confirmation experience: Students verify scientific principles by following a given procedure, often referred to as "cookbook labs"

- Structured inquiry: Students are given a step-by-step procedure.

- Guided inquiry: Students devise their own procedure to solve the problem.

- Open inquiry: Students formulate their own problem to investigate.

In essence, inquiry strongly suggests that the learner is his own teacher, with the teacher acting as "a guide on the side." Inquiry requires that students participate actively, and interact directly, with the content. Therefore when inquiry is conceptualized as a teaching approach, the teacher's role is to engage students in student-directed inquiries about scientific phenomena, refine their critical and scientific thinking skills, and help them learn to work collaboratively with peers as they engage in science investigations (Luft, 2001).

2.2 Professional Development Centered on Inquiry Approach

There are several studies which suggest that inquiry-based professional development can positively change both beliefs and practices of classroom teachers. Inquiry-based professional development is one model that promotes opportunities for in-service teachers to practice reform-based instruction in science classrooms (Dass 2001; Luft, 2001; Radford, 1998).

The effectiveness of the inquiry-based professional development is prominently on teachers have opportunity to investigate and construct their own knowledge. The model of professional development is usually based on the aim such as improving teacher content knowledge, pedagogy knowledge and skill or belief in teaching. Many studies adopted inquiry as approach in professional development for teachers' greater learning. The example of inquiry-based professional development model is "immersion experience in inquiry science" (Loucks-Horsley, 2003) It is one strategy gives teachers opportunity to learn about science. The experiences are designed as mentored research opportunities for teachers. It helps teachers build knowledge through the problem solving in real classroom and with the guidance of experts in science and science education. However, inquiry approach in professional development models need more integrations a) emphasizing on the specific needs of teachers (Luft, 2001); b) learning in real situation (Radford, 1998); c) committing teachers to practice new ideas after short training (Dass, 2001; Luft, 2001; Radford, 1998) and d) evaluating teachers' effectiveness of new practice in the context of their own teaching situation (Dass, 2001)

Conclusion of the Need for Inquiry-based Professional Development

As these studies suggest, inquiry-based professional development can help inservice teachers engage students in science inquiry learning effectively. It can provide them with the knowledge needed to assist students in identifying researchable questions, designing and conducting experiments, developing explanations, thinking critically about the relationship between evidence and explanations, and communicating scientific procedures and explanations (NRC, 1996). Based on the recommendation of these studies, inquiry serves as an integral component of the professional development model at the centerpiece of this study. Most inquiry-based professional development models engage teachers in long-term sessions and in active learning processes.

3. The Need for Reflective-based Professional Development

3.1 Defining Reflection

According to Cooper (1999) reflection plays a prominent role in effective decision-making that adds to one's body of knowledge for use in future situations. Teacher reflection may take place before, during, and after teaching. Reflective terminology, however, is being used in various ways, and is informed by diverse theoretical frameworks. Calderhead and Gates (1993 cited Dewey, 1933) emphasizes the need for teacher educators to develop certain attitudes of open-mindedness and skills of thinking and reasoning in order to shape the way that teacher educators think about reflective teaching. Schon (1983) gave the notions of reflection-on-action and reflection-in-action. Reflection-on-action occurs when the professionals think about what they are doing. Reflection-in-action focuses on professionals engaging in reflective conversations within practical situations, where they constantly frame and reframe a problem as they work on it, testing out their interpretations and solutions.

3.2 What Research Says about the Benefits of Reflection in Practice

Science content knowledge and knowledge of how to teach science are important competencies of science teachers. Many elementary science teachers have weak understandings of science content, pedagogy, and pedagogical content knowledge (Heywood and Parker, 2002; Summers, 1992; Trend, 2001). Professional development plays an important role in helping science teachrs develop competence, capability and positive beliefs toward teaching (Chumchit, 1992). In previous times, professional development programs attempted to increase teachers' knowledge often through approaches which simply transmit the information or describle implications of educational theory. These approaches do not effectively help teachers link their knowledge of classrooms to educational theory (Cheangkool, 1999; Jurawatanaton, 2003; Keawdang, 1998; Marx *et al*, 1998). Therefore, more sustained and complex approaches are required.

Modern educational wisdom moves beyond professional development that simply addresses the concern for translating theory of teaching into practice. It shifts to the notion of linking practice and theory to provide better conditions for learning to teach. Experience in the practice of teaching has been seen as valuable as it provides a context for teachers' personal explanations or theories (Northfield, 1998). Therefore a professional development model should include activities that link the theory and practice of teaching. In this study, assumptions surrounding the notions of "inquiry" and "reflection" plays an important role in designing a professional development model which helps teachers conceptualize the ways in which school experience contributes to learning to teach throughout their career.

Ferraro (2000) described two benefits of reflection for classroom practice. First, she notes that reflection helps teachers develop a deeper understanding of their own teaching style which ultimately helps them become more effective practitioners. The other specific benefit included the validation of teachers' ideals, beneficial challenges to tradition, recognition of teaching as artistry, and respect for diversity in linking theory to classroom practice. Because of its potential for improving teacher teaching, reflection is considered a vital part of professional development.

3.3 Professional Development and Reflection

Research on professional development for in-service teachers has shown that critical reflection experience continues to be an effective technique for facilitating change in belief and practice. Occasional large-group sessions like workshops, should include reflective activities such as study teams and peer coaching in which teachers continuously examine their assumptions and practices (Ferraro, 2000). According to Loucks-Horsley (2003) professional development strategy should provide opportunities for teachers to reflect deeply on teaching and learning in order to gauge the impact of the changes they have made on their students, and think about ways to improve. Many studies on professional development introduced reflection to enhance teacher learning (Briscoe and Wells, 2002; van Driel *et al.,* 1998; Marx *et al.,* 1998; Nichols *et al.,* 1997) The reflective process in professional development studies were designed in various ways to support teacher learning, for example, small group discussion and reflection on experience through many reflective tools such as journals, portfolio, cases, learning maps, storied re-told, metaphors, and proverbs. The effectiveness of reflection on enhancing teachers' learning is the central to this study for teachers reflecting deeply on teaching and learning.

Conclusion of the Need for Reflective-based Professional Development

Reflective practice plays many different roles across diverse educational studies. For example, reflection is used to help practitioners frame and reframe a problem, test the interpretations and solutions, develop deeper conceptual understandings, or make sense of new practice. There is no doubt that reflection plays an important role in professional development. Many studies of professional development use reflective tools such as journals, cases reaction, writing cases, and metaphors. These tools are used as effective vehicles to help teachers think deeply through a reflective process.

Outline of the Study

This research aimed to investigate the effect of developing and using the reflective, inquiry-based professional development model for upper-elementary science teachers. This model attempted to a) improve in-service elementary teacher understanding and practicing inquiry teaching and b) develop a structure of the sustain professional development model focusing on teachers' collaborative working.

In order to develop an understanding of how a professional development model is planned, translated, and experienced, the researcher needed to interpret existing data from the field to create emerging concepts and categories that shed light on the research questions. This study was conducted using an interpretive methodology which emphasizes the basic principle that researcher discover and communicates the way in which people who are studied make sense of and give meaning to, their interactions with each other (Erickson, 1986)

This study had two distinctive phases: (1) exploring elementary science teachers' needs in professional development and developing a reflective, inquiry-based professional development model and (2) implementing the reflective, inquiry-based professional development experience. The first phase was to investigate upper-elementary science teachers' needs of professional development in science and their current situation of science teaching. The findings from this phase were used as a fundamental data for developing professional development model. The researcher developed a reflective, inquiry-based professional development model, training manual and materials. In the second phase, teachers from schools, located in Pathum Thani educational service area office 1, participated in a three day workshop. Moreover, modified lesson study process was implemented for sustaining contact to see the effect of professional development model on teachers change and growth on their inquiry teaching.

Purpose of the Study

The purpose of this study was to develop and implement a professional development model designed to provide elementary teachers opportunities for constructing knowledge and practicing their knowledge of inquiry teaching through inquiry and reflection in the context of Thai science education. Many activities were introduced to emphasize, for example, integrating new learning with prior knowledge and beliefs, immersing in inquiry, and reflecting on practice. As noted earlier, professional development for science teachers has been characterized as a shift in emphasis from transmission of knowledge to experiential learning that focuses on reflection and collaborative learning. The model of professional development envisioned in this study was premised on the idea that understanding is facilitated when teachers collaborate on authentic understanding of theory (Marx *et al.*, 1998; Vanzee and Roberts, 2001; Zembal-Saul *et al.*, 2002)

To study the development and implementation of this professional development model, the following research questions served as the centerpiece of deliberation:

1. What are Thai elementary science teachers' professional development needs?

2. What happens when a professional development program for Thai elementary science teachers is planned, translated, and experienced?

2.1 How are characteristics of a professional development model conceptualized, designed and implemented to facilitate elementary science teachers' learning based on notions of reflective and inquiry-based practice?

2.2 How does teachers' narrative knowledge with respect to the teaching of earth science evolve during a professional development experience?

2.3 How do teachers translate what they learn through the professional development experience into classroom practice?

Anticipated Outcomes

This study was anticipated that the professional development model would effectively improve teachers' understanding of inquiry and inquiry practice in authentic classroom. Moreover, Thai science educators could apply the findings of this study for professional development in Thailand.

Delimitation of the Study

This research was comprised of two main methods of case study and narrative to develop teachers' understanding and practice of earth science inquiry teaching through the reflective, inquiry-based professional development model. During and after the workshop, four teachers were asked to participate in a more in-depth case study. The case study was conducted with the four teachers in order to develop a deeper understanding of the influence of inquiry/reflective-based professional development. These four teachers were selected on the basis of their ability to provide theoretical insight into the topic under study and willingness to participate for an extended period of time. The key researcher (PhD science education student) worked closely with four teachers in the second semester of academic year 2006. The data collected in relation to each research question was illustrated in Table 1.1 and was discussed in depth in chapter 3 of this study.

Subjectivity and Personal Bias

I felt that inquiry teaching is not easy for many teachers. My interest in designing professional development with a focus on inquiry and reflection stemmed from my experiences in my own teaching as a student teacher and my experience in observing other teachers in elementary school. During my student teaching, I mostly used lecture in teaching science to seventh grade students. I found that lecture didn't help them to learn science. I wanted to change my teaching by emphasizing more inquiry. After changing my teaching to include more inquiry, the students were more attentive and liked science activities. However I was not able to implement inquiries successfully, because at that time I didn't know much about inquiry teaching. For me, my initial attempt with inquiry teaching was an experiment. I felt that I needed to learn more about how to teach science using an inquiry-based approach. After I received my teaching diploma, I continued my Ph.D. studies. I had the opportunity to observe an experienced teacher. In the second semester of the academic year 2003, I personally observed a fifth grade teacher. This teacher had two years of teaching experience. She taught all science content for grade five including meteorology. My observations of her teaching revealed a pattern: every time she began her class with question, followed up with an experiment or demonstration and finished the lesson with her own conclusion about the experiment. Her activities were simply hands-on. She failed to engage her students' minds in the activities. Students were doing science step by step in a cookbook fashion dictated by the teacher. When the experiments were finished, all conclusions were derived from the teacher. Her science activities were not meaningful for students, because they had no opportunity to connect their ideas and prior knowledge with the activities they were doing in class. When I asked her about general problems in teaching meteorology, she described the biggest challenges as lack of knowledge about meteorology, difficulties in finding interesting activities for teaching meteorology, and difficulty in communicating the abstract nature of some meteorology concepts to young children.

Table 1.1 The matrix for research question and data collection

Research Questions	Rationale	Subjects/Documents	Data Collection							
			Need	Interview	Journal	Case reaction	Classroom	Metaphor	Field note	Document
1. What are Thai elementary science teachers' professional development needs?	Express need for professional development	4^{th}-6^{th} science teachers (50 schools in Pathum Thani)	x	x						
2. What happens when a professional development model for Thai elementary science teachers is planned, translated, and experienced?	To examine in depth the process of planning and implementing a professional development model effect to teachers									
2.1 How are characteristics of a professional development model conceptualized, designed and implemented to facilitate elementary science teachers' learning based on notions of reflective and inquiry-based practice?	Researches say that reflection, inquiry, and contextual knowledge are the important aspects of teacher learning	Documents about Thai science education, professional development, inquiry, and reflection								x

Table 1.1 (Continued)

Research Questions	Rationale	Subjects/Documents	Data Collection							
			Need	Interview	Journal	Case reaction	Classroom	Metaphor	Field note	Document
2.2 How does teachers' narrative knowledge with respect to the teaching of earth science evolve during a professional development experience?	To investigate teachers using their narrative knowledge to make changes in their classrooms	Four case studied teachers			x	x	x	x		
2.3 How do teacher translate what they learn through the professional development experience into classroom practice?	To examine the development of teacher cognition on inquiry teaching	Four case studied teachers		x	x	x	x	x	x	x

All of the above subjectivities led to my interest in designing professional development for elementary science teachers by using inquiry and reflective based models. The focus on inquiry-based approaches was intended to help teachers learn through experience how to teach science in inquiry. The emphasis on reflection was intended to help teachers revise their teaching and find effective ways to improve it.

Salient Terms Important to This Study

1. Professional development model

Professional development model in this study refers to the design of science teacher learning experiences that emphasize linking theory and practice (Northfield, 1998), are long-term and continuous over time, respond to teachers' needs, and provide a follow-up phase to check teachers' progress (Fetters *et al.*, 2002). Specific strategies of the change process for science teachers will be taken in to account. The activities will be designed to integrate inquiry-based instruction using the 5-E model of inquiry, to encourage teacher learning.

2. Inquiry

This study defines inquiry in term of scientific inquiry based on common characteristics of scientists' investigations and a logical progression (Carin *et al.*, 2005 ; Cuevas *et al.,* 2005). The 5-E model of inquiry was used in the design of the workshop activities. The 5-E model consists of five phases of science investigation: a) engagement, b) exploration, c) explanation, d) elaboration/extension, and e) evaluation.

3. Reflection

This study considers reflection as a process which helps teachers develop deep and significant understandings in the construction of new knowledge (Schon, 1983; Cruikshank 1987; Zeichner and Liston, 1987). Reflection is implicit not only in practice or in one's personal thoughts, but also in social, institutional and broad policy contexts in which practice takes place (Day, 1999). This study uses reflective tools such as journals, classroom case, and metaphor (Nichols *et al.,* 1997) to help teachers consider on how their science knowledge develops, and how new strategies or lessons they design fit with science standards of the Institute for Promoting of Teaching Science and Technology (IPST, 2003.)

4. Narrative Knowledge

This study considers narrative knowledge to be a form of *story-telling* (Polkinghorne, 1988). Individuals can draw on narrative knowledge by interpreting experiences or events that reflect a more general understanding of similar situations (Carter and Doyle, 1996). This study uses narrative knowledge (case knowledge and metaphors) for examining the experiences of individual teachers in order to understand their development of teaching practice (Cole and Knowles, 1993; Connelly and Clandinin, 1990). In this study, teachers' narrative knowledge and belief are the same construct.

Based on many scholars, teacher knowledge is discussed in many categories. Teacher knowledge explicit in teachers' narrative is identified as teacher narrative knowledge. The following terms are the description of teacher narrative knowledge of this study which is used to present the conceptual framework for data analysis.

Knowledge of curriculum is the concept of the set of experiences that influence learning (Elbaz, 1981). For this study, how the teacher organized the experiences for student learning is dependent on how teachers organize the experience for student learning and how teachers conceptualize curriculum. Knowledge of curriculum is viewed in three elements of organizing experience in content, method, and evaluation (Porland and del Pozo, 2004)

Knowledge of instruction is the knowledge that teachers derive from practices such as instructional routines, classroom management, student needs, abilities, and interests (Elbaz, 1981). This study focuses on this type of knowledge as the teaching strategies which teachers know for overall instruction processes or sequences for inquiry teaching. These processes or sequences could present the level of inquiry by using a Science Teacher Inquiry Rubric (STIR) to see the features of inquiry in teacher knowledge and their classroom instruction (National Research Council, 2000 and Beerer and Bodzin., 2004).

Knowledge of subject matter is focused on the structure of knowledge which the teacher must understand, how knowledge is constructed, how it is organized in the disciplines, the source of teachers' structured knowledge, and the factors that influence the processing of knowledge (Elbaz, 1981 and Geddis, 1993).

Knowledge of self is a personal aspect which leads teachers to work toward personally meaningful goals in their teaching (Elbaz, 1981).

Knowledge of Milieu is an interactive aspect which shapes teachers' knowledge based on a variety of interactions with others in their environment, such as peers, students, administrators, prevailing social ethos, and encounters with researchers (Elbaz, 1981).

5. Teacher Growth

Professional growth involves changes over time in the behavior, knowledge, images, beliefs, or perceptions of teachers (Kagan, 1992). To facilitate professional growth, this study considers the outcomes and settings of professional learning (Carter, 1990). The outcomes of this professional development model will focus on earth science content knowledge and inquiry-based teaching practice. The setting in the study provides the environment or conditions that can support growth for the participants.

6. Teacher Change

Teacher change is a process that needs time and many elements (Fullan, 1993) to help teachers use new practices. In this study, teacher change focuses on recognizing needs, making plans to improve, engaging in new practices, and allowing time to evaluate the effectiveness of the new practices.

Summary and Preview

This chapter presented an overview of the study. Chapter 1 began with a description of the Thai educational reform context, the status of elementary curriculum in Thailand, professional development in Thailand and a rationale for the study. Research questions guiding the study were introduced along with the purpose of the study. The theoretical framework and methodological framework which ground the study were briefly described. The personal biases which contain the interpretation of research were presented and discussed. Chapter 2 reviews the literature regarding teacher knowledge, reflection, inquiry, professional growth and change. Chapter 3 presents the framework which supports the methods used to collect and interpret data. The methodological framework will be described in the sections of general methodology, methods of the study, context of the study, procedures of the study, and data collection and analysis. Chapter 4 presents the result of the first phase "Exploring and developing a reflective, inquiry-based professional development model. This chapter describes about the guiding principles of the professional development model, teachers' needs and their current teaching situation, and the process of constructing the professional development model. Chapter 5 describes the findings of two cases from Radbumrung School. Chapter 6 presents the findings of two cases from Thamma School. Chapter 7 presents the conclusions, discussion and recommendations of this study.

CHAPTER II

REVIEW OF LITERATURE

Introduction

This study purposed to design a professional development model for Thai elementary science teachers. Chapter two begins with a review of the surrounding notions of literature on “teacher knowledge.” The chapter continues by reviewing salient literature about reflection and inquiry, as these serve as the theoretical underpinnings for the professional development model designed in this study. The last part of this chapter reviews literature about professional growth and teacher change.

Teacher Knowledge

This part of the review of literature describes what is known about teacher knowledge and related research. There are many types of teacher knowledge present in research in education. Many educational scholars emphasize the importance of studying teacher knowledge. This review is intended to synthesize and clarify studies that address various forms of teacher knowledge. This review also focuses on narrative knowledge that involves the expression of teachers’ experience in which knowledge and beliefs are hidden. Teachers’ narrative knowledge is particularly important in this study as a tool for examining teachers’ professional growth.

1. Defining and Considering the Components of Teacher Knowledge

There were a variety of ways scholars discussed questions related to the knowledge base about teaching and teacher education. Fullan (1993) stressed the importance of teacher knowledge in the teaching profession, particularly as an element of teacher empowerment. They pointed out that an expansion of teacher roles and responsibilities would never take place unless there was a corresponding expansion of teacher knowledge. They described teacher knowledge as “the knowledge that empowers teachers to pursue their craft with confidence, enthusiasm, and authority is knowledge of the teaching profession, in the broadest possible sense" (Lichtenstein *et al.,* 1992: 41).

Many other aspects of teacher knowledge were suggested by several researchers. According to the work of Elbaz (1983), a teacher's practical knowledge was defined as the practically-oriented set of understandings which were used to shape and direct the work of teaching. Elbaz categorized teachers' practical knowledge into five areas: knowledge of self, milieu, subject matter, curriculum development, and instruction. The notion of practical knowledge also figured prominently in the work of Connelly and Clandinin (1988). They referred to the critical element in their work as "personal practical knowledge." They described this form of knowledge as follows:

> Personal practical knowledge is in the teacher's past experience, in the teacher's present mind and body, and in the future plans and actions. Personal practical knowledge is found in the teacher's practice. It is, for any one teacher, a particular way of reconstructing the past and the intentions of the future to deal with the exigencies of a present situation (Connelly and Clandinin, 1988: 25)

Connelly and Clandinin (1990: 12) also viewed teachers as holders of practical knowledge, stating that "what is at stake is less a matter of working theories and ideologies and more a question of the place of research in the improvement of practice and of how researchers and practitioners may productively relate to one another." From this perspective, it became necessary for educational researchers to find ways of learning what teachers knew without using methods that distorted, destroyed, or reconstructed this knowledge. They emphasized and adopted the techniques of narrative and story as ways of avoiding the excessive imposition of external theories and constructs on the personal practical knowledge of teachers.

Shulman (1987) focused on teacher knowledge based on teaching. He purposed the seven categories of teacher knowledge which were content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristic, knowledge of educational context and knowledge of educational aims. A large number of studies that considered the knowledge-research base for teacher education focused particularly on pedagogical content knowledge (Geddis, 1993; Levonen, 2004; Mulholland and Wallace 2005; Veal, 2004; Zembal-Saul *et al.,* 2002). The term Pedagogical Content Knowledge (PCK) described knowledge of the representations, analogies, and strategies useful for teaching about a particular topic. The components of PCK were typically considered to be content knowledge, knowledge of student, knowledge of context and pedagogical knowledge. However, Veal (2004) noted that many researchers also added additional components such as curriculum, media and assessment, depending on the purpose of their research.

Teacher knowledge was examined in many later studies with similar categories as those of Elbaz (1983) and Shulman (1987). Vries and Beijaard (1999) believed that teacher knowledge consisted of teachers' views on the objectives of education, the contexts of the curriculum, and the role that adults and students played in the teaching and learning process. For novice teachers who had little professional experience. Lichtenstein *et al*. (1992) categorized the essential kinds of knowledge empowered teachers possessed into three areas: knowledge of professional community, knowledge of educational policy, and knowledge of subject area.

There were many studies that focused on teacher knowledge in the context of professional development. Studies of teacher knowledge were typically based on assumptions about what teachers knew and how their knowing was expressed in teaching (Connelly *et al.,* 1997; Fenstermacher, 1994). Many types of teacher knowledge have been studied across diverse settings. The section that follows reviews what is known about the development of teacher knowledge among these diverse contexts.

2. Teacher Knowledge in the Context of Professional Development

The majority of studies focusing on teacher knowledge studied the context of professional development for science education centered on PCK (Driel *et al*., 1998; Levonen *et al.*, 2004; Mulholland and Wallace 2005; Veal 2004; Zembal-Saul *et al.,* 2002). Most of the studies of PCK investigated how teachers developed their planning and actions in their classroom. However two important studies about teacher practical knowledge were found in the works of Connelly *et al*. (1997) and Chen (2005). Both studies investigated practical knowledge as a dynamic process of learning and change, and examined its dialectical relationship involving theory and practice. A variety of narrative data were used in a study conducted by Connelly *et al*. (1997), which focused specifically on the development and expression of teachers' personal practical knowledge. They conducted a case study of one classical music teacher in China. This study used a variety of methodological steps. First, they collected field texts (notes taken in a teacher's classroom), field notes, interviews, conversations, journal writing, autobiographical writing, letters between teachers and researchers, oral histories, annals, chronicles, teacher stories, family stories, photographs, memory boxes and other personal/family artifacts. After that, they analyzed these data and came up with ideas to make sense of teacher knowledge. They categorized these ideas using organizers such as images, rules, practical principles, personal philosophies, metaphors, cycles, rhythms, and narrative unities. They tied these ideas together in terms of a theory of narrative and story telling. A finding of this study was a deeper understanding of a broad conceptual view of how teachers' personal practical knowledge developed in the context and influence of the environment in which they worked. They referred to the environment in which teachers worked as a "landscape". Their metaphor of landscape was important because it captured the exceedingly complex intellectual, personal and physical environment for teachers' work.

3. Teacher Knowledge in the Context of Professional Development for Elementary Science Teachers

An example of PCK development in the context of in-service elementary science teaching was a study conducted by Mulholland and Wallace (2005). They studied the development of one elementary science teacher's knowledge over a 10-year period. Their longitudinal study was focused on understanding the teacher's development of PCK or adopted view of PCK. The study highlighted the teacher's knowledge at three critical points in her career: student teacher, beginning teacher, and established teacher. The researchers used a combination of unstructured and semistructured interviews, participant observation, journals, and field notes to construct field texts to help them understand the development of teachers' knowledge (Clandinin and Connelly, 1994). In the process of data analysis, they initially organized field texts by analytic induction (Erickson, 1986). Then, they generated themes and used these themes to link events and ideas and make sense of what was happening in the classroom. They also constructed narratives of the growth and development of the teacher's PCK. Finally, they analyzed the portraits of narratives through use of a teacher knowledge framework.

There has been increased interest in studying other types of teacher knowledge such as narrative knowledge, a type of practical knowledge (Cole and Knowles 1993; Connelly and Cladinin 1990; Polkinghorne 1988), particularly in the context of knowledge based professional development. According to the literature on knowledge based professional development, the most recent studies reveal what teachers' know by using narrative tools such as journal writing and other various reflective strategies. Teachers' narrative knowledge in this study is an important type of sense-making strategy, necessary for teacher growth in the professional development context.

4. Teachers' Narrative Knowledge

Narrative knowledge is one type of comprehension that is a component of personal practical knowledge. In education, many studies used personal narrative knowledge for examining the experiences of the individual teacher in order to understand his/her development of personal practical knowledge (Cole and Knowles, 1993; Connelly and Clandinin, 1990). According to Carter and Doyle (1996: 124), "personal practical knowledge is the sense of how individual teachers come to understand local, everyday events and decisions in their classrooms as part of their life narratives." From this perspective narrative knowledge was useful in helping teachers understand and make decisions about practice.

According to Polkinghorne (1988) the general meaning of "narrative" referred to any spoken or written presentation. To further explicate the meaning of "narrative", Polkinghorne (1988: 13) gave a specific description; "narrative can refer to the process of making a story, to the cognitive scheme of the story, or to the result of the process—also called *stories*, *tales*, or *histories*."

In Polkinghorne's research, he preferred to use the term "narrative" to refer to both its' process and results. Carter and Doyle (1996) also used the term "narrative" as a process utilized to interpret experiences or events that reflected a more general understanding of similar situations. After interpreting, individuals drew on their own knowledge as narrative knowledge. This knowledge could be drawn from a variety of remembered experiences, bits of information, beliefs, knowledge, dispositions, commitments, and cultural forms, as well as the tasks at hand. Similarly, Clandinin and Connelly (1994) suggested that narrative knowledge was a way by which teachers knew their lives in terms of stories; their way of being in the classroom was storied.

The terms "narrative" and "story" were often collapsed, however these two words can be distinguished by usage. Clandinin and Connelly (1988) used "story" to refer to particular situations such as classroom field records or interview data. They used the word "narrative" to refer to longer-term life events. They used the term narrative exclusively to refer to research, research method and researchers who engaged in the collection of stories. Similarly, Scholes (1981) argued that a story was a special kind of narrative, or a story with a certain, very specific syntactic shape.

Studies involving teachers' narrative knowledge generally featured four elements important in the construction: experience, time, personal knowledge, and reflection and deliberation. These elements reminded the researcher about the purpose of narrative. Clandinin and Connelly (1988) pointed out narrative construction was practical because it was concerned with a person's experience in time. Besides experience and time, personal knowledge played an important role in understanding how teachers made sense of teaching and learning. Connelly and Clandinin believed that knowledge was constructed through a dynamic relationship between individual and social context. The individual had a unique educational history. This relationship was dynamic in that the social experience was a reconstruction of personal life stories in which the larger social structures, themselves, were influenced by personal action. In many studies of narrative knowledge, reflection and deliberation were methods of practical inquiry. The two terms tended to point in different temporal directions. Reflection was used to imply a preparation for the future, while deliberation was used to imply past consideration. Since narrative requires a treatment of past, present, and future, it was necessary to consider the ideas of both reflection and deliberation.

Sometimes narrative was used to stimulate reflection on what an individual knows. Because narrative was the expression of person, many studies in education used narrative as a reflective tool to represent teachers' practice (Mattingly, 1991). In this sense, there were many kinds of data involved in the narrative method, including stories, cases, and metaphors. In the context of professional development, the research conducted by Baker and Digiovanni (2005) represented the advantage of using narratives. Their study focused on teacher narrative responses to the standardized curriculum, particularly in terms of reaching diverse populations and filling gaps between students' home and school culture.

4.1 Storied Knowledge

Stories present actions through a diachronic rendering that, in the process of unfolding, reveals contexts and lives (Mattingly, 1991). To understand an individual's personal narrative knowledge, story becomes important data for revealing this kind of knowledge. Especially in education, studies of teacher narrative knowledge rely on stories.

Carter and Doyle (1996) suggested that story represented a way of knowing and thinking that was particularly suited to explicating the knowledge that had arisen from action. Thus, story was an especially relevant form for expressing teachers' practical understandings. Carter (1993: 6) emphasized that

> …story was a mode of knowing that captures in a special fashion the richness and the nuances of meaning in human affairs; we could come to understand sorrow or love or joy or indecision in particularly rich ways through the characters and incidents. This richness and nuance could not be expressed in definitions, statements of fact, or abstract propositions. It could only be demonstrated or evolved through story.

The importance of teachers' stories on the study of teachers' knowledge was also the focus of Connelly, Clandinin *et al*. (1997: 669) work. They highlighted the important role of story in teachers' work emphasizing that "the story is a construction and, therefore, is a step in the movement from field texts (data) to interpretation and research knowledge…It is something which has an empirical base, is an interpretive construction, and is told for a larger research purpose."

Mattingly (1991) also described the potential power of using storytelling as the basis for action research, noting that storytelling was something practitioners already do. An action research design that made practitioners self-conscious about their storytelling could reframe this undervalued mode of oral discourse as a form of reflection on practice. Simply asking practitioners to reflect on the stories they had already told provided a natural bridge to a serious inquiry about the very deepest layers of value and belief that under girded the decisions they made.

The effectiveness of story in capturing teacher story knowledge was also examined in a study conducted by Cooner and Tochterman (2004). In their study, storytelling was used in the context of professional development. They used stories to examine elementary science teachers' growth and change through professional development. They reported that even experienced teachers could reflect on their experiences and learn new or different lessons from teacher stories each time.

Story was a way for persons to present their knowing or thinking. Cladinin and Connelly (1988) referred to how particular situations in the classroom could represent what teachers held as their knowledge. The use of teacher stories to capture what teachers knew was of benefit for science educators in studying teachers' professional knowledge. Carter and Doyle (1996) preferred the terms "interpretation" and "understanding" as vehicles for capturing the personal narrative or life story. Using interpretation and understanding of teacher stories to learn more about teachers' knowledge was a tool that was often called "case-based pedagogy."

4.2 Case Knowledge

Carter (1993) noted that there were two activities that involved the usage of stories. These activities were case studies and case narratives. Case studies were methods that used cases as data for the analysis of teaching. Case narrative was the use of cases as instruments for teacher education.

Cases were normally constructed by building a story. McAninch (1993) explained that cases were storied phenomena of practice or events that could be theoretically interpreted, because case knowledge and theoretical knowledge were intricately linked. Shulman (1986: 12) added that "in describing an event the case must be explicated, interpreted, argued, dissected, and reassembled… Hence, there is no real case knowledge without theoretical understanding." Based on the work of Shulman (1986: 11), case knowledge was "knowledge of specific, well documented, and richly described events." Similarly to Shulman's idea, McAninch (1993) used the term case to refer to the product of a theoretical inquiry, much the same as a case was the product of a legal proceeding. Both of these researchers used the term narrative to refer to a description of an incident or event that could be formulated into a case through theoretical interpretation and inquiry, although it was important to point out that stories or descriptions of events comprised only a subset of the items in experiences that could potentially have become cases. McAninch (1993) maintained that cases could be useful in teaching theory, because they could pull the abstract down to the level of practice; they could provide an apparatus by which teacher candidates could examine the relative contributions of an array of theories to the understanding of a particular situation. Additionally, McAninch noted that cases may address the experiential and practical orientation of teacher candidates to a greater extent than abstract textbook prose. In describing the features of good case narratives, McAninch also suggested the following: a) narratives that described real events were better than those that were fictional, b) narratives should have been as experiential as possible, c) narratives sought to be vivid and compelling, and d) narratives should have been sufficiently broad and complex that real effort must have been exerted to impose the theory on them. In this way, writing a case would have been a form of solving the problem for the writer.

Cases were used for professional training in many fields such as law, medicine, business, political science, journalism, architecture, educational psychology and measurement. Cases in these fields have been used in a variety ways to shape practitioners' knowledge. In science education, cases were used for teacher preparation as a basis for analyzing conceptions of effective teaching. There were several common themes in science education that illustrated how cases served as foci for research agendas. These themes included cases as tools for professional preparation and development, cases as discipline-based teaching methods, cases as tools for facilitating critical thinking and exploring dilemmas, and cases as an assessment tool (Koballa and Tippins, 2000).

Tippin *et al.* (2002: 5) described the interest in the use of cases in teacher education, noting that "…cases and case-based pedagogy stems from the increasing belief in their value as a tool for helping perspective and practicing teachers to develop skills of critical analysis and problem solving, acquire broad repertoires of pedagogical techniques, develop higher-order cognitive thinking, and engage in reflective practice." Moreover cases had historically been used in a variety of formats including the critical incident, protocol, vignette, simulation, video case, and interactive video case. There were many examples of studies which used case-based pedagogy for supporting teachers' problem solving, decision making, and reflective practices.

In science education, several studies involving the use of cases stood out. One example of the use of case-based pedagogy was presented in the study of Dori and Herscovitz (2005). They used case-based pedagogy over a long-term period to educate and train 50 science teachers at the elementary level. Teachers who participated in this professional development program gradually shifted from exposure to new teaching methods and subject matter, to active learning and preparation of case-based team projects, and finally to interdisciplinary, action classroom teaching using cases that they had developed. Their study indicated that cases were effective tools to develop enhanced teacher learning. After teachers gained an improved understanding of teaching through case-based pedagogy, they were able to apply their case knowledge to the classroom as a strategy for teaching science.

The previous two sections describe how stories and cases are effective tools for capturing teacher knowledge. The following section proposes another narrative that can represent what teachers know in their teaching. This narrative (metaphor) is used as a tool that can help teachers to construct or reflect on their knowledge.

4.3 Metaphor

Metaphor was a specific kind of knowledge that Connelly *et al*. (1997) included as a component of personal practical knowledge. Metaphor was unique in that it was more linguistic, less structured. Moreover metaphors gave imaginative expression to personal practical knowledge making it possible for a person to explore hidden intellectual avenues of belief. Tobin and Tippins (1996) noted that metaphors always had some element of surprise that may have invited new perspectives and assisted individuals to see the familiar in totally new ways. In this sense, metaphors could help teachers to stimulate the construction of analogical relationships and facilitate conceptual change. Pugh *et al*. (1997: 18-19) noted the metaphor's use as a heuristic device:

> Metaphor becomes, then, a device for exploring the unknown in terms of the known, for helping us to discover and understand new knowledge. It is a tool of insight. It provides us with a perspective for comprehending something unknown by comparing it to familiar objects and experiences... When we say that metaphor is a heuristic device, we mean that it leads to discovery-in particular, the discovery of new knowledge and new understandings.... In

helping us to discover new knowledge, metaphor builds on our prior knowledge and thus has potential in improving both teaching and learning.

In teacher education, many researchers have used metaphors as a way or tool for generating teacher knowledge. Ritchie *et al.* (2006) suggested that metaphor had the significant implications for improving the quality of science teaching, because metaphors operated as a master switch that allowed sets of practices and associated beliefs and values to be enacted. Knowles (1994) explored the notion of metaphor as a window to pre-service and beginning teachers' personal histories and related these histories to the conceptualization of reflection in teacher education. Similarly, Tobin and Tippins (1996) suggested that metaphors could be a tool to generate knowledge when a person wants to make sense of a new experience. What was already known by someone could be linked to what is not known. That is, a new experience was initially conceptualized in terms of something that was known. In addition, metaphors could be a tool for reflection on action for teachers that could help them improve their teaching. Tobin and Tippins (1996: 711) purposed that "metaphors are portrayed as one of several ways in which knowledge about science teaching can be re-presented and as potential foci for critical discussions about enacted science curricula and powerful tools for generating new ways of thinking about teaching and learning of science."

Generally a metaphor provided links between an image and the verbal description associated with it. It was a link between new and existing knowledge. It was also a link between language and images. These connections may have had significance to the potential application of metaphors in building knowledge of teaching and improving the quality of instruction. Teachers, in describing metaphors, provided insights into associated images and narratives that could have helped them build their action in teaching and hone a routine from that action (Tobin and Tippins, 1996).

Metaphor was used as a tool to help teachers construct knowledge of science teaching in Greves's (2005: 99) secondary teacher education course "The Butterfly Project". The instructor used the metaphor "students like butterflies" to describe how “butterflies come in different shapes, sizes, and colors, and with a different variety of backgrounds, talents and vulnerabilities – as will the students in your future classrooms.” This helped pre-service teachers construct ideas about their future students. The results of this study demonstrated that metaphors could be expanded to provide a transformative, reflective experience in fostering pedagogical knowledge and connecting theory to practice. The effectiveness of metaphor in creating teacher knowledge was also studied by Ritchie (1994). This study used metaphor as a starting point for teacher reflection aimed at improving practice. Ritchie described how a teacher used metaphor to transform her teaching in ways which were more consistent with constructivism. After a period of time the teacher taught in a more routine manner and was less reliant on the need to use the metaphor to guide her teaching practices. Use of the metaphor allowed the teacher to focus on the facilitation of student learning and to use strategies that minimized the disadvantages of a lack of content knowledge.

5. The Role of Teacher Narrative Knowledge in This Study

Teachers’ narrative knowledge is particularly important in this study as a tool for examining teachers’ professional growth. From the review of the literature, it could be seen that narrative knowledge was useful in helping teachers understand and making decisions about practice. Therefore the endeavor of science educators in trying to capture teacher knowledge from their narrative was facilitated through the use of many types of narrative tools. These tools, for example, cases and metaphors, were of interest in helping teachers develop their teaching knowledge. Cases were used as pedagogy for helping teachers to develop skills of critical analysis and problem solving, acquiring broad repertoires of pedagogical techniques, developing higher-order cognitive thinking, and engaging in reflective practices (Tippins *et al.,* 2002). This study uses case-based pedagogy to help teachers learn and gain knowledge of teaching in the area of earth science. Moreover, metaphor is used in this study as a tool to help teachers construct knowledge to build their actions in teaching and hone a routine from that action (Tobin and Tippins, 1996).

Reflection

This section of the literature review focuses on reflective approaches to teaching. In this section, definitions and components of reflection are considered. Moreover the application of reflection in the context of science education is discussed with a focus on understanding how science educators use reflection to help teachers develop their teaching practice.

1. Defining and Considering the Components of Teacher Reflection

The Reflective process is an effective way to help learners develop knowledge because it acknowledges that emotional intelligence is an important part of the learning process. According to Brockbank *et al*. (2002), reflection had an energizing effect on the learner, which promoted deeper learning. There was widespread agreement (Schon, 1983; 1987; Cruikshank 1987; Zeichner and Liston, 1987) that the reflective process was crucial in helping teachers develop a deep and significant understanding in the construction of new knowledge.

The development of knowledge through reflective processes was initially studied by Schon (1983: 26). He suggested that two forms of reflection could be used to describe the tacit knowing implicit in action. Reflection-on-action was "thinking back on what we have done in order to discover how our knowing-in-action has contributed to an unexpected outcome…." Reflection-in-action centered on "the way that thinking serves to reshape what we are doing while we are doing it." Furthermore, Schon (1987) mentioned that the reflective process typically involved problematic situations where practitioners rethought (reflect in) or thought back (reflect on) about critical events. In the process of reflecting on problematic situations, practitioners could come up with new knowledge appropriate to different situations.

A number of researchers have attempted to study different levels of reflective practices in teachers (Adler, 1991; van Manen, 1977; Zeichner and Liston, 1987). These researchers acknowledged that in the educational field, reflection played an important role in enabling teachers to bring appropriate knowledge and experience to bear on their classroom practice. The notion of the teacher as a reflective practitioner has provided a framework for making sense of the connections between theory and practice. In 1987, Zeichner and Liston proposed three levels of reflection that constituted the notion of the teacher as a reflective practitioner. The first level was the technical level which focused on the efficient application of professional knowledge to goals and objectives. Through this type of reflection, teachers reflected on the effectiveness of their teaching strategies. The second level of reflection proposed by Zeichner and Liston was concerned with teaching in the context. This level of reflection made teachers think beyond the use of strategies in teaching to an examination of how contexts influenced teaching and learning. Zeichner and Liston's last level of reflection involved moral and ethical issues. In this level of reflection, teachers had a concern for justice and equity, which guided their thinking about teaching and learning.

In a review of the teacher education literature, there were three predominant perspectives toward reflection (Adler 1999; van Manen, 1977). These perspectives were "Reflecting on the Technical and Practical", "Reflection in Action", and "Reflection as Critical Inquiry". The first perspective, described by Adler (1999), focused on the technical and practical, and centered on teachers' choices of teaching strategies with respect to the content, context and goals of teaching. According to Cruikshank's study (1987), pre-service teachers developed this type of technical reflection through structured laboratory experiences, such as microteaching, that assisted in developing pre-service teacher competence. Reflection in action, based on Schon's research (1983; 1987), was the second perspective of reflection commonly found in the literature. Reflection in action helped practitioners build explicit knowledge and made it useful for thinking through observation and reflection while "in the thick of things" (Adler 1999). As emphasized by Zeichner and Liston (1987), reflection as critical inquiry was the third perspective. This model of reflection as critical inquiry emphasized the importance of developing teaching within existing contexts. This perspective incorporated awareness of ethical and political possibilities. It involved developing the ability to make decisions about teaching and learning based on perceived ethical and political consequences and an awareness of alternatives.

There were two forms of reflection (Brockbank, *et al*., 2002). The first form, self-reflection, had the advantage of preventing the potential for self-delusion. The second type of reflection was reflection-with-others, or dialogue. This form centered on the idea that dialogue had the power to challenge and bring different perspectives to the learner. It also included the important element of recognizing the cultural power of an organization by allowing issues of influence, authority, status, class, race and gender to emerge and affect learning and professional growth. Similarly, Day (1999) noted that reflection was implicit not only in practice or in one's personal thoughts, but also in social, institutional and broad policy contexts in which practice takes place. He also argued that reflective practice had important implications for the improvement and professional growth of practitioners.

According to many scholars writing about notions of reflection, there was an important relationship between reflective thinking, new knowledge and action. In this sense, the reflective process involved dialect between thought and action, which ultimately led to a change in practice. Carr and Kemmis (1986: 33) described this relationship between thought and action as follows:

> The ideas that guide action are just as subject to change as the action itself. Therefore, only though a fundamental shift in our beliefs, values and feeling about teaching and learning, will we be effective in bringing about significant change in our practice, creating a culture of critical reflection enhances our educative potential, and provides practitioners with opportunities to deconstruct conventional practices.

Many science educators have studied the dialectic in the research between thought and action represented in the reflective process. The research of Nichols *et al*. (1997) emphasized the importance of the connection between school practice and social contexts. In this sense, the relationship between hidden and overt curriculum, pedagogical approaches and forms of evaluation, and the development of historical consciousness were important parts of the reflective process. When the focus was on developing within existing contexts, critical reflection became an important aspect of professional development. Adler (1999) suggested that the pedagogy used to promote critical inquiry and reflection must be designed to encourage students to question, analyze, and consider alternatives within an ethical and political framework and to reflect on (and in) that action. Nichols *et al*. (1997) also proposed the idea of "tools" and "toolkits" as terms to indicate how pre-service teachers saw their own pedagogical commitments. These reflective tools consisted of portfolios, journals, classroom cases, learning maps, stories re-told, metaphors, and proverbs. They briefly described about classroom cases and metaphors as follows:

> Classroom cases are teacher narratives that can serve as an interpretive framework, enabling learners to actively construct knowledge as they draw on their own background experiences to make personal sense. A case is a description of a real or realistic classroom situation that incorporates all the facts needed to clarify and solve target problems. Cases which are used as reflective tools can be categorized as open or closed cases. Open cases involve unresolved dilemmas, while closed cases are centered on dilemmas with a resolution. When teachers write open or closed cases, they may exchange them with classmates who write a solution to the open cases and react to the closed cases (Nichols *et al.,* 1997: 85).

Metaphor encouraged socially mediate personal constructions which served as a holistic way of representing knowledge.

> Metaphors can serve as holistic ways of re-presenting knowledge about science teaching and learning. When prospective and practicing teachers construct metaphorical understanding of experience they ground them in individual semantic systems and beliefs embedded in the culture in which they live. Metaphors are useful in understanding science teaching and learning across numerous contexts, including: (a) metaphor as a tool for conceptualizing teacher and learner roles, (b) metaphor as a way of framing events, problems, and solutions, (c) metaphor as a vehicle for facilitating teacher change in beliefs and practice, and (d) metaphor as a way for teachers to represent their professional relations (Nichols *et al.,* 1997: 91).

According to Nichols *et al*. (1997), most reflective tools aimed to promote inquiry and enabled pre-service teachers to think out loud, in written or oral forms, and get feedback from others. In general, these reflective tools allowed teachers to confront their personal beliefs and ideas, and to explore their assumptions further.

2. The Role of Reflection in In-service Professional Development

Most researchers generally agree that reflection both in and on action are essential to building, maintaining and further developing the capacities of teachers to think and act professionally; therefore, reflection is useful in helping teachers develop their professional knowledge. In the context of inservice professional development, Loucks-Horsley *et al*. (2003) proposed a number of strategies that provided opportunities for teachers to reflect deeply on teaching and learning. Those strategies were a) action research, b) study groups, c) lesson study, d) case discussions, and d) examination of student work. The purpose of these strategies was for "engaging teachers in examining their experiences in the classroom, assessing the impact of the changes they have made on their students, and thinking about ways to improve. These strategies also encourage teachers to reflect on others' practice, relating it to their own and generating ideas or improvement" (Loucks-Horsley *et al.,* 2003: 115).

A reflective approach was used by O'Sullivan (2002) and Wise *et al*. (1999) in their work with professional development for inservice science teachers. O'Sullivan studied the effectiveness of reflection for teachers participating in the Inservice Education and Training (INSET) program. This program aimed to implement reflective approaches in the training of unqualified and under qualified primary teachers in Namibia. A "structured reflection" was used by the trainer to support reflection in the teachers' practice. Using structured reflection, the trainer closely guided teachers' reflection during a professional development workshop. The results of the study suggested that structured reflection could enable teachers, within their professional capability at the beginning of a training program, to reflect on new skills and the rationale for using them.

Wise *et al*. (1999) used reflection to assess how teachers made sense of and tried new ideas. These authors believed that reflection was one of the factors essential in delivering effective professional development programs. They introduced reflective practice methodologies to participants as a vehicle for making sense of their use of new teaching strategies in the PEERS Academy Workshops. The reflective practice was intended to help teachers consider how strategies or lessons fit with standards, how well they worked for students, and the type of assessment needed to determine students' understanding. The results of their study showed that the majority of teachers reported that reflective practice was beneficial in helping them learn how to apply mathematics and science standards and create active learning environments.

In terms of using reflective tools in the professional development of inservice teachers, Briscoe and Wells (2002) introduced self-reflection as a part of experienced elementary science teachers' action research. The teachers used journals and portfolios as effective tools for improving their practice. Briscoe and Wells found that self-reflection helped teachers develop solutions to the difficulties they encountered in teaching. Day (1999) studied reflection-with-others or "dialogue" as a tool for teacher professional development. Day included the context of fundamental values and beliefs about education in his idea of reflective learning. He purposed five orientations to reflective practice. These consisted of the immediate, the technical, the deliberative, the dialectic and the transpersonal. He also linked the concept of reflective practice to peer partnerships and networks such as "collaboration". He suggested that in the process of collaboration, new knowledge and skills needed to be developed and tentative steps toward change needed to be supported.

3. The Role of Reflection in This Study

This study uses reflection as a vehicle for helping teachers make sense of new knowledge and the use of new teaching strategies. This study emphasizes the use of reflective tools to help teachers think deeply on their action. As described earlier, reflective process is dialectic between thought and action (Carr and Kemmis, 1986). Considering the aforementioned dialectic, this study focuses on the use of reflective tools to enable teachers' meaningful learning by thinking back on action that helps them to improve new action. This study adopts many types of reflective tools such as journal, classroom case, and metaphor in the workshop and follow up. These reflective tools enable teachers to construct new understandings of how to facilitate earth science for an inquiry learning approach.

Inquiry

This portion of the literature review initially examines various definitions and components of inquiry. It is followed by a critique and synthesis of studies centered on inquiry-based approaches in the context of professional development. The purpose of this section is to explore how studies of inquiry-based professional development incorporate the inquiry experience as part of teacher learning.

1. Considering Definitions and Components of Inquiry

Inquiry is a term advocated by Cuevas *et al*. (2005) including investigative skills, actively seeking answers to questions about specific science concepts, and developing abilities to engage, explore, consolidate, and assess information. Moreover, they noted that the common framework of inquiry was that it began with a question based on observation, which ultimately led to a conclusion based on evidence. This process was normally seen in how scientists worked. Rakow (1986) said that scientists were question askers; any observation they made have may been the catalyst for an investigation. Scientists developed hypotheses and drew inferences from direct observation of natural phenomena and withheld judgments until all the data had been accumulated. According to Rakow, they must have been open-minded enough to set aside previously held views in light of new information.

Inquiry approaches were advocated in science education because it made more sense to teach students the logical thinking skills needed to construct knowledge. Students were thereby better prepared to acquire new knowledge. According to Rakow (1986), students used hands-on investigation and experimentation to learn about their world. The skills that students needed to carry out investigations and experiments were collectively referred to as science process skills. Rakow also suggested that students needed basic process skills and integrated process skills in order to do science.

2. Instructional Models of Inquiry Learning Cycle

Bybee et al. (2006 cited Dewey, 1933) mentioned that the conception of thinking which could be connected to scientific inquiry. Dewey's instructional approach was based on experience and required reflective thinking which in contemporary terms meant the learning experience was "hands-on and minds on." Dewey's instructional model consisted of six phases: (a) sensing perplexing situations, (b) clarifying the problem, (c) formulating a tentative hypothesis, (d) testing the hypothesis, (e) revising rigorous tests, and (f) acting on the solution. However, the role of the teacher was as the main instructor to help students do hands-on and minds on activities. In sensing perplexing situations, the teacher presented an experience where the students felt thwarted and sensed a problem. After that, the teacher helped the students identify and formulate the problem during the 'clarifying the problem' phase. The teacher also helped students in formulating a tentative hypothesis by providing opportunities for students to form hypotheses and establish a relationship between the perplexing situation and previous experience. The teacher allowed students to try various types of experiments including imaginary, pencil-and-paper, and concrete experiments, to test the hypothesis. In revising rigorous tests, the teacher suggested tests that resulted in acceptance or rejection of the hypothesis. Finally, the teacher asked the students to devise a statement that communicated their conclusions and expressed possible actions.

In the late 1950s and early 1960s, an era of curriculum reform, instructional models were popularized by leaders of the reform movement. One of those instructional models was "guided discovery" designed by Atkin and Karplus (1962). The inquiry learning process consisted of three phases: exploration, invention, and discovery. An exploratory activity was designed to encourage students to investigate a particular topic. To utilize inquiry effectively, the teacher must have used questioning techniques as a tool for promoting student thinking. The second phase of guided discovery was termed invention. Students were asked to consider what they believed they had learned from examining the content in the exploratory phase. The third phase was discovery. In this phase students discovered the inadequacies of what they had invented, reconsidered their invented rules and modified them so that they had general application. These three phases of inquiry provided a framework within which the teacher could work with students.

The Biological Science Curriculum Study (BSCS), a team whose Principal Investigator was Roger Bybee, developed an instructional model for constructivism in the mid-1980s. This philosophy about learning proposed that learners needed to build their own understanding of new ideas connected to their prior knowledge (Bybee *et al.,* 2006). It was called the “5E Instructional Model.” There were five processes promoting opportunities and events encouraging students to build their own understanding through (a) engagement, (b) exploration, (c) explanation, (d) elaboration, and (f) evaluation. It was fundamentally equivalent to the three phases of guided discovery by exploration, explanation and elaboration. The new phases presented in the 5E instructional model were engagement and evaluation. The process of engagement aimed to engage students in the learning task. The students mentally focused on an object, problem, situation, or event. The activities of this phase made connections to past experiences and exposed students’ misconceptions. They should have served to mitigate cognitive disequilibrium. The evaluation process was an important opportunity for students to use the skills they had acquired and evaluate their understanding. The teacher also could have completed a formal evaluation in this phase.

Even though there were many instructional models of inquiry, Bibens (2001) mentioned that inquiry was not a magic formula, but if combined with a command of subject content and a reasonable degree of expertise in working with students, it could be a tremendously satisfying experience for both teacher and students. Windschitl (2002) maintained that the level of effective inquiry teaching was dependent on interaction between teachers and students. There were many forms of inquiry practice in classrooms. These could be distinguished by the degree of independence students had in asking and answering questions. Windschitl (2002) described the different forms of inquiry as follows: the lowest levels of inquiry were “confirmation” experiences, often referred to as cookbook labs, in which students verified known scientific principles by following a given procedure. The next level was referred to as "structured inquiry" in which the teacher presented a question for which the students did not know the answer, and students were given a procedure to follow in order to complete the inquiry. In "guided inquiry," teachers provided students with a problem to investigate but the methods for resolving the problem were left to the student. In "open or independent inquiry" teachers allowed students to develop their own questions and design their own investigations.

Songer *et al*. (2003) provided evidence that classroom-based inquiry was usually found in settings with teachers who were self-starters and who tended to have a great deal of initiative, autonomy, and support for the range of innovative programs and ideas they implemented. In addition, Rakow (1986) suggested that the successful inquiry teacher was one who had specific behaviors and attitudes that contributed to successful inquiry teaching. Specifically, Rakow noted that successful inquiry teachers should model scientific attitudes, demonstrate creativity, flexibility, effective questioning strategies, and show concern both with thinking skills and with science content. Songer *et al*. (2003) also emphasized that the inquiry teacher should have many resources and supports for students, including assistance from administrators, educational researchers, technology experts, and/or parent/guardians.

The importance of inquiry in the science classroom was a concern of many science educators. To establish classroom-based inquiry, science teachers needed to have both knowledge of science content and how to teach science as an inquiry process (Rakow, 1986). Therefore, there were many professional development programs that aimed to encourage inquiry and develop the essential characteristics described above.

3. Inquiry Practice in the Context of Professional Development of Science Teachers

There were many studies about inquiry practice in the context of professional development (Crawford *et al.,* 2005; Lee *et al.,* 2004; Lunsford, 2002; Songer *et al.,* 2003; Windschitl, 2002). These studies could be divided in professional development for pre-service (Crawford, 2005; Windschitl, 2002) and inservice science teachers (Lee *et al.,* 2004; Lunsford, 2002; Songer *et al.,* 2003). Songer *et al*. (2003) studied the implementation and adaptation of "Kids as Global Scientists" (KGS), an inquiry-based, technology-rich middle school learning environment. This program aimed to support teachers in developing an understanding of inquiry thinking, including explanation building, prediction making, and the integration of conceptual understandings of foundational scientific ideas with the productive application to naturally occurring problems in atmospheric science. The professional development framework was made up of four components: collaborative construction of understanding, enactment of new practices in classrooms, reflection on practice, and adaptation of materials and practices (Blumenfeld *et al.,* 2000). This framework guided the five strands that made up the year-long KGS professional development effort. Teachers attended summer workshops and Saturday work sessions, participated in an online teacher message board, had access to in-class support during enactment, and used curricular materials provided by the KGS team. The summer workshop was focused on the enactment component including the productive use of technology, weather content, hands-on activities, and an inquiry-based pedagogical framework. Complementing the summer workshop were Saturday work sessions occurring once a month. These work sessions allowed teachers to plan together with help and input from the university team and other teachers, and to develop solutions to enactment difficulties they had had in the past or ones they had foreseen in the years to come. In the year 2000, the KGS Weather program was implemented simultaneously in 230 classroom settings with 230 teachers and 13,000 fourth-ninth grade students from 40 states. Data collected and analyzed were from two populations. These populations were a large sample of 57 teachers and a small sample of five teachers and 225 students. The data collected from the large sample included: preprogram registration surveys, and post program teacher surveys. These data were used to characterize teachers' demographic and background characteristics, beliefs about science teaching, reactions to the KGS program, and views on support of the KGS program in their classroom. Data collected from the small sample included teacher interviews, teacher registration, post-program surveys, student pre-and posttests measurement, content and inquiry knowledge, teacher logs and classroom observation forms. These data were used to characterize the nature of student learning outcomes, including both multiple-choice and open-ended measures of scientific knowledge, and inquiry thinking, as well as details on teacher beliefs, reflections on KGS enactment, and reflection on the support of reform programs. The results from participating teachers showed that their classrooms were successful with inquiry, as indicated by students' significant positive gains on open-ended and multiple-choice assessments.

Two other studies (Lee *et al*., 2004; Lunsford, 2002) of professional development for inservice science teachers focused on the trends with inquiry-based professional assessment. These two studies are examples of inquiry-based professional development used to assess teacher change. The first study was conducted by Lunsford (2002). In this study, a workshop was designed for inquiry-based modular professional development. The workshop provided 20 inservice secondary school science teachers with direct experiences in physical science inquiry-based investigations. The teachers were divided into groups of three or four to produce a team learning environment suited for guided discovery and problem-solving activities. Inquiry experiences were intended to increase subject matter knowledge, pedagogical understandings, and ability to design modular activities in the classroom. The workshop consisted of three components: a three-week summer institute, a follow-up workshop, and classroom visitation and further support through an Internet website. The three-week institute immersed participants in how to develop and implement an inquiry and cooperative learning environment and address pedagogical issues. After returning to school, the participants attended follow-up workshops. During these workshops, teachers reflected upon their efforts in implementing inquiry-based lessons in their classroom and provided feedback on the positive and negative aspects of using inquiry-based learning with their students by creating a portfolio. Data analyzed from pre- and post-tests and questionnaires showed that teachers had changed their opinions about science instruction to reflect more of a belief in inquiry-based instruction that focused on understanding of scientific concepts and applying the contents to solve problems. Lee *et al*., (2004) conducted a study focused on professional development in science instruction for 53 inservice elementary teachers. This study addressed teachers' beliefs and practices related to inquiry-based science and the impact of the professional development intervention on their beliefs and practices related to inquiry-based science teaching. The design of this study emphasized inquiry activities that enabled teachers to provide effective science instruction in their classroom. Four full day workshops emphasized instructional units, and materials designed to complement them. The first three workshops were aimed at addressing specific issues pertaining to the instructional units. Workshop activities were structured to encourage active involvement of all teachers, as they reflected on their own beliefs and practice toward inquiry-based instruction, offered suggestions to other participants, and shared insights about similarities and differences in the teaching and learning environments across their schools. The results described the extent of change in teachers' beliefs and practices related to science inquiry and science content.

To study how well teachers implemented the essential features of inquiry in classroom instruction, Beerer and Bodzin (2004) developed a Science Teacher Inquiry Rubric (STIR) according to inquiry standard provided by the National Research Council (NRC, 2000). This tool was to measure teachers' understanding and implementation of inquiry based science instruction. The researchers used the STIR to observe 12 randomly selected study group teachers both before the study groups met and at the end of six professional development sessions to see whether teachers changed their instruction. Overall, they found that all 12 of the observed study group teachers included student-centered essential features of inquiry in their classrooms during the post-observation, and two teachers reached the level of full essential features of inquiry taking place in the classroom.

The above studies suggest that inquiry experience for teachers is important in preparing teachers for inquiry classrooms. To support inquiry experiences for teachers, professional development experiences can be designed in many ways. Examples consist of the collaborative model of the KGS professional development which includes workshops and follow-up workshops (Songer *et al.,* 2003), and inquiry-based professional development workshops for inservice teachers (Lunsford, 2002). The tool to measure teachers' understanding and implementation of inquiry was developed to help teachers reflect on their teaching practice with colleagues (Beerer and Bodzin

2004). These models and measurement tools of professional development all aim to help teachers learn about how to teach using inquiry approaches in their classroom.

4. The Role of Inquiry-based Professional Development in This Study

This study shares a similar purpose of supporting inquiry teaching for Thai inservice elementary teachers who are not familiar with this approach. The studies reviewed in this section emphasize the importance of integrating inquiry experience and reflection on practice into professional development models. In order to design a reflective, inquiry-based professional development model, this study provides opportunities for teachers to develop their teaching through the framework of collaborative construction of inquiry, the development of narrative understanding and direct experience with inquiry investigations and reflection on action.

Professional Growth and Teacher Change

This section of the literature review examines definitions and components of professional growth, teacher change, and related current trends. It also describes models of professional growth in science teacher education, taking into consideration how notions of teacher change and professional growth are related specifically to this study.

1. Definition and Components of Professional Growth and Teacher Change

It is very important to explicate the relationship between professional growth and teacher change in the context of professional development. Furthermore, teacher growth and change are important elements to consider in the design of professional development.

Kagan (1992) described "professional growth" as changes over time in the behavior, knowledge, images, beliefs, or perceptions of teachers. In teacher professional growth, many instruments, mostly narrative and reflective tools, were brought to capture the growth (Kayler, 2003; Mattingly, 1991; Tippins *et al.,* 2002).

Teacher growth is different from teacher change. The above paragraph explains teachers' growth as a product of positive change that can captured by narrative and reflective tools. Teacher change is a process that needs time and many elements (Fullan, 1993) to help teachers implement new practices. For example, Boling and Martin (2005) explained the process of change assumes the teacher recognizes a need, makes plans to improve, engages in the improvement, and allows time to evaluate the effectiveness of the new practices.

Carter (1990) noted that there are many idiosyncratic generalizations about the processes of teacher growth. To more fully clarify the meaning of teacher growth Carter identified two component outcomes and settings. Teacher growth outcomes included attitudes, dispositions, orientations, perspectives, knowledge, concerns, or commitments. Carter (1990) pointed out that the second component of teacher growth, settings, was sometimes loosely defined and varied widely across studies. In general, the notion of "settings" in professional development referred to the environment or conditions for change (Loucks-Horsley *et al*., 1998). The teacher change process was not always smooth because the environment contained resistance that could disrupt or distort how professional development appears to teachers. Therefore, it was very important to create the right "setting" or environment for professional development if change was to occur. Loucks-Horsley *et al*. (1998) described the four "P's" that were critical to the success of any change effort. These critical ingredients must be considered in every effort aimed at change to ensure success:

- People: their needs, motivations, behaviors, and the roles they play in change

- Processes: how change progresses over time and what can be done along the way to ensure its success

- Practices: characteristics of the innovation being introduced

- Policies: the pressure of push from policy makers and administrators that takes the form of mandates, guidelines, regulations, expectations, and direction

Other researchers included additional elements that they believed essential for teacher change. In order for the type of professional growth described by Kagan (1992) to occur, Fullan (1993) identified eight necessary elements. He generated these ideas by reviewing eight basic lessons of schooling that brought about a paradigm shift for him. According to Fullan, those elements needed to bring about professional growth and change in teachers included the following:

- Conflict is a necessary part of change in school

- New behavior must be learned

- Team-building extended to the entire school

- Process and content are interrelated

- Finding time for change enhances prospects for success

- A big vision with small building blocks can create consensus and progress

- Manageable initial projects with wide involvement and visible concrete results sustain the restructuring process

- Facilitators, along with opportunities for training and for retreats, are critical components of successful restructuring efforts.

According to Fullan (1993), productive educational change was full of paradoxes and components. These paradoxes and components included caring and competence, equity and excellence, and social and economic factors all of which impacted teachers. The complexity of the change process was also mentioned by Sikes (1992) who explained that teacher change had its origins in a variety or a combination of factors such as economic trends, historical events, different political parties coming into power, social and cultural developments, demographic trends, or technological advances.

Fullan (1993), in discussing approaches to generating change in teachers, focused on four core capacities as the generative foundation for building greater change capacity. The four change capacities described by Fullan consisted of personal vision-building, inquiry, mastery, and collaboration. Moreover, Sikes (1992) suggested that in the change process, teachers were continually required to alter their administrative and organizational systems, their pedagogy, curriculum content, the resources and technology they used, and their assessment procedures. They were also required to acknowledge their ‘inadequacies’ which could potentially support learners to acquire the best education. Furthermore, Nias *et al*. (1992) suggested that several key factors were related to the continuous improvement of teachers. These factors consisted of (a) teacher learning, (b) teacher sharing of beliefs and practices over time, (c) working conditions for continuous learning and continuous development, and (d) the internal and external policy and environment of the school.

Based on the above views, there are two factors that appear central to the process of teacher change. The first factor involves concerns about teachers themselves. According to Fullan (1993) and Nias *et al*. (1992), teacher learning was the key to the development of a curriculum which improved the quality of children’s education. According to Fullan, teacher learning should be based on inquiry. Fullan also emphasized that inquiry was the essential activity that engaged teachers to form their personal purpose for self-renewal. He suggested strategies that were available to facilitate teacher inquiry learning including reflective practice, personal journals, action research, and collaborative working in innovative mentoring and peer settings. The second factor that is essential to the process of teacher change involves the environment that provides the opportunity for change. Learning environments should have a collaborative atmosphere where teachers can work together in teams.

2. Current Trends in Professional Growth and Teacher Change

Most inservice teacher professional development has traditionally occurred in the form of short workshops or conference attendance designed to foster teachers’ awareness or interest in deepening their knowledge and skills. However, these approaches for professional development appear insufficient to foster teacher learning in ways which alter what they teach and how they teach. Research has shown that these approaches had little long lasting impact on teachers' growth as practitioners (Kayler, 2003; Shields *et al.,* 1998; Wise *et al*, 1999). These types of professional development models for practicing teachers were often criticized for being delivered out of the teaching context, disconnected from the realities of school and classroom, and separated from teachers' individual professional interests and needs. In essence, according to Kayler (2003), these traditional professional development models usually resulted in a disconnected and decontextualized set of experiences which did not foster teacher learning.

The challenge for the professional developer was to find ways that supported teachers' growth continuously, connected to their practice and contextualized in their local school. Recent research highlighted new models of professional development which conceptually took the form of collaboration (Fullan, 1993 and Nias *et al.,* 1992) or involved a set of long-term, on-going experiences. Collaborative action research (Levin and Rock, 2003) was an example of one of these new forms of collaborative professional development which provided teachers with opportunities to get involved and become more reflective, critical and analytical when they thought about their teaching style in the classroom.

Recent research also explored the premise that professional development characterized by a number of contact hours and sustained over a period of time has a stronger impact on teacher growth than short-term workshops or similar models (Corcoran 1995; Darling-Hammond 1995; Hargreaves and Fullan 1992; Hiebert 1999; Lieberman 1996; Little 1993; Richardson and Placier, 2001; and Stiles *et al,* 1996). These researchers suggested that sustained learning opportunities for teachers in the context of professional development should provide teachers with sufficient time, activities and content necessary to increase knowledge and encourage meaningful changes in their classroom practice. Some of the new types of professional development activities included: (a) study groups where teachers were engaged in regular systematic reflection in and on their practice, (b) coaching or mentoring arrangements where teachers worked one-on-one with an equally or more experienced teacher, (c) networks which linked teachers in person or electronically to explore and discuss topics of interest, pursue common goals, share information and address common concerns, (d) immersion in inquiry where teachers engaged in the kinds of learning that they were expected to practice with their students (Loucks-Horsley *et al.,* 1998) and (e) lesson study where teachers worked collaboratively on a small number of lessons by planning, teaching, observing, revising, and reteaching them (Chokshi and Fernandez, 2005). In comparison to the traditional 'one-hit' workshops, these types of activities were usually longer in duration and allowed teachers to practice and reflect on their teaching.

3. Professional Development in Science Teacher Education

The concern for translating theory of teaching into practice in the context of science teacher education has had a significant impact on the development of new professional development models with closer links between theory and practice. Northfield (1998) noted that experience in the practice of teaching provided a basis for personal explanations or theory. Therefore professional development programs should include activities which relate the theory and practice of teaching. The related place of theory and practice in professional development programs help teachers conceptualize the ways in which school experience contributes to learning to teach throughout their career. Fetters *et al.* (2002) found that professional development should be long term in nature with follow-up phases involving classroom teaching. Other researchers agreed that this follow-up phase was needed to gradually change teachers' beliefs and influence teachers' practices (Bryan and Atwater, 2002; Levitt, 2001; and Raths, 2001).

In order to support teachers' efforts to construct their own knowledge, professional development should emphasize, for example, integrating new learning with prior knowledge and beliefs, applying ideas to practice, and reflecting on the results. These new approaches to professional development for science teachers have been characterized as a shift in emphasis from transmission of knowledge to experiential learning that focused on collaborative learning. According to Marx *et al*. (1998), Vanzee and Roberts, (2001) and Zembal-Saul *et al*. (2002), understanding was facilitated when teachers collaborated on authentic problems in a manner that required them to justify their practices in light of emerging understanding of theory. New efforts to design professional development programs should take into account a variety of models that reflect this shift in thinking.

Koballa and Tippins (2001) reviewed several professional development models that contributed to reducing the gap between the theory and practice in school. The TEAMS model, Co-teaching model, and Problem-based learning (PBL) model all shared characteristics including problem solving, reflection set within an authentic context and co-learning processes in small groups. These three features were important as they emphasized the teacher as an active learner in the process of learning to teach. Moreover each model seemed to be identified with a norm toward which all science teachers should clearly be moving. However, as Koballa and Tippins pointed out, it was apparent that differences in professional learning goals and the context in which teacher learning takes place contributed to the diversity across these programs. According to Northfield (1998), the various models of professional development could be generally characterized into behavior, apprenticeship, and development approaches.

Professional development models based on the behavior approach were more traditional, focusing on transmission of knowledge to teachers. This model was exemplified by the traditional workshop format. The apprenticeship model was based on the idea that knowledge construction was tacit and closely depends on context; therefore, it focused on the work of teachers and their contributions in teacher learning. An example of the apprenticeship model was TEAMS which was mostly used in pre-service or novice teacher development. This model attempted to make visible to pre-service or novice teachers the understandings, skills and reasoning of scientists and science teachers through cognitive apprenticeship. In this approach novice teachers could observe and practice with experts. Lastly, the developmental approach saw learning as the continual reshaping of teachers' personal beliefs. In this approach, teaching was seen as a continual search for understanding. Moreover, to make the strong link between teaching and theory, collegiality was necessary for continually reshaping teachers' beliefs. Developmental models emphasized that school experience could encourage teachers to develop new beliefs and understandings; therefore, teaching in schools should be presented as having a research perspective. The Co-teaching model was a good example of the developmental approach. The Co-teaching model had a design and context that reflected the genuine needs of teachers. This model also emphasized that teachers use reflection and that teachers learn in practice. Some professional development models involved more than one approach. The Problem Based Learning (PBL) model was a hybrid combining aspects of both apprenticeship and developmental approaches. It included contextual learning experiences with classroom cases to address the knowledge-base for teaching and the use of many of the cognitive apprenticeship methods such as coaching, scaffolding, articulation and reflection. The PBL model also used co-learning processes with peers to guide the development of personal beliefs about science teaching.

These three models (TEAMS, Co-teaching, and PBL model) ultimately stressed the need to move beyond the science teacher education notion of translating theory into practice to a notion of providing better conditions for learning to teach (Northfield, 1998; Koballa and Tippins, 2001.) From the perspective of learning to teach, teachers were expected to be the active learners in the process.

Professional development, when conceptualized as creating better conditions for learning to teach, needed to include appropriate strategies. Many studies recommended an employment of strategies as a way of articulating a comprehensive approach to changing science classrooms and changing teachers' practices in science (Sherry and Gibson, 2005; Loucks-Horsley *et al.*, 1998)

4. Lesson Study as the Effective Professional Development Model

Based on ideas about new models (TEAMS, Co-teaching, and PBL model) of professional development that emphasized the link between practice and theory, the need to provide better conditions for learning to teach science and strategies for the change process, science teacher education needed to feature innovative ways of conceptualizing professional development. Lesson study was one of the professional strategies which allowed inexperienced and new teachers an apprenticeship based on close observation and analysis of the practice of others before venturing to try an aspect of a new procedure themselves (Dudley, 2003). Lesson study (jugyoukenkyu), an inquiry model of teacher professional development, was used extensively throughout Japan and had begun to capture worldwide attention as a potential strategy for enhancing teacher professional development (Lewis and Tsuchida, 1998; Lewis, 2000; Dudley, 2003; Saito *et al.,* 2006; and de la Cruz, 2007).

Chokshi and Fernandez (2005: 674) described lesson study in the following manner:

> Lesson study begins with a group of teachers identifying a common goal and a content area to focus on. Then, as a concrete way to explore how to achieve their chosen goal, teachers work collaboratively on a small number of lessons by planning, teaching, observing, revising, and reteaching them.

According to Lewis, Perry, and Hurd (2004) and Lewis (2002), lesson study became an important tool for instructional improvement for several reasons: (a) increased knowledge of subject matter, (b) increased knowledge of instruction, (c) increased ability to observe students, (d) stronger collegial network, (e) stronger connection of daily practice to long term goals, (f) stronger motivation and sense of efficacy and (g) improved quality of available lesson plans. Lesson study provided a focus on integrating knowledge of subject matter with instruction. Moreover, Lewis (2000) pointed out that teacher self-critical reflection was emphasized and esteemed. Both teachers and students set goals for self-improvement in a quest for character improvement.

Rock and Wilson (2005) emphasized that social constructivism was the theory that provided an essential rationale for the lesson study process as a potential method for increasing teacher professional knowledge and development. There were three principles of social constructivism that supported teachers' learning during the process of lesson study. First, teacher knowledge was constructed in response to social interactions through social negotiation, discourse, reflection and explanation. It also enhanced learning through formation of a structured zone of proximal development

(Vygotsky, 1949). Second, teacher study groups worked while confronting problems or discrepant events that supported them acquiring knowledge and organizing their own experiences (Fleury, 1998, Prawat and Floden, 1994). Finally, teachers were activated to reflect on their experiences, to create understanding, to evaluate their understanding, and to explain their understanding to others through the lesson study process. It related that knowledge was the result of active mental processing by the individual in a social environment (Cobb and Yackel, 1996; Prawat, 1996). These principles of social constructivism underlay lesson study and validated why each step of the lesson study process was important in bringing about increased professional knowledge and skills.

5. Lesson Study and Teacher Change and Growth

Many studies used lesson study as a model for professional development. The findings showed teachers' change and growth through the process of lesson study (Kolenda, 2007; Rearden *et al.,* 2005; Rock and Wilson, 2005). Two studies adopted the process of lesson study as a model of professional development. Another study adapted the process of lesson study by using it during a workshop and named the process "workshop study". All studies showed success of teachers' professional growth and change. Rock and Wilson (2005) studied the effects of the lesson study process on six upper-elementary teachers. The participants worked in two groups with each group consisting of three members. The researchers served as the lesson study facilitators. The team members worked together through the eight steps of the collaborative lesson study that included: (1) defining and researching the problem, (2) planning the lesson, (3) teaching and observing the lesson, (4) evaluating the lesson and reflecting on its effects, (5) revising the lesson, (6) teaching and observing the revised lesson, (7) evaluating and reflecting a second time, and (8) sharing the results (Stigler and Hiebert, 1999). The in-depth understanding of the lesson study process and its meaning for teachers were analyzed from various data sources which were interviews, field notes/observation, and reflection journals. The researcher found that teachers change and growth were involved with stimulating sustained work, teachers' confidence in sharing experiences and beliefs, peer collaboration, reading and sharing professional literature, and consulting with experts.

The second study used lesson study as a part of professional development. Kolenda (2007) studied a school district's experiment with a Japanese lesson study. The lesson study was one part of the study. There were 3 programs to incorporate teacher change in both curriculum and instructional strategies. The first program was the Understanding by Design (UbD) model. It was a full day workshop about curricular revision in science focusing on processes for development of assessment and design of learning activities and strategies. The second program was entitled Schools Around the World (SAW). This program was a full day workshop. It provided a systematic approach that examined actual teacher designed assignments with respect to clarity of language, alignment to standards, level of student engagement and the degree to which higher order thinking skills were employed. The last program, lesson study, had allowed teachers to share and adopt the best practices. The teams in lesson study consisted of three to six teachers in grades two through eleven. After the lesson study program, team members had provided very positive feedback regarding their experience including the value of collaboration and self-reflection in the lesson study process to help empower them and become better teachers.

The last example of effectiveness of lesson study for professional development focused on adapting the process of lesson study into a workshop format. Rearden *et al*. (2005) adapted steps of lesson study to form a workshop study model. They used the lesson study process to analyze a professional development workshop for the purposes of tailoring the content, resources, and collaborative efforts to better meet the needs of the participants. The workshop study consisted of similar steps of lesson study including: (1) focusing the workshop by articulating goals, (2) planning the workshop format and content, (3) conducting the workshop, (4) reflecting on and evaluating the workshop, (5) revising the format and content of the workshop, (6) implementing the revised workshop, (7) reflecting on and evaluating the revised workshop, and (8) sharing the results of the analysis. The participants in this study consisted of 40 teachers from 20 schools. Teachers attended the workshop as teams comprised of one mathematics teacher and one science teacher. After the workshop, teachers were effectively presenting a higher-level of the content knowledge. They also combined pedagogical tools for translating the content into forms that were useable. Moreover, they had greater awareness of the connections between mathematics and science.

From above examples of professional development studies, lesson study is one of the effective professional development models because of its nature which provides opportunities for teachers in inquiry, collaboration, reflection, and long-term classroom context. These are important elements to support teachers learning on content and pedagogy knowledge and conduct change and growth sustainable for their teacher profession.

6. Conceptualizing Professional Growth and Teacher Change for This Study

Teacher change is a demanding process in this study. According to Wilson and Berne (1999), professional development activities with small numbers of volunteer teachers had more effect on teacher professional growth and could produce changes in their knowledge, beliefs, and practices. According to the Institute for Promotion of Teaching Science and Technology (IPST, 2003), reform oriented practice for science instruction in Thailand should focus on inquiry. IPST suggested that teachers should encourage students to pose questions, use hands-on activities, assist students make sense of the data, offer explanations to students based on evidence, and analyze and evaluate students' alternative conceptions. In addition, there was an urgent need to prepare teachers with new ideas or concepts to change their practice. Pillay (2002) reported that Thai teachers are technicians who follow procedures rather than professionals who understand both the theoretical (principles, assumptions and facts) as well as the practical (procedural and actions). The Education Act of Thailand (1999) in section 23 of chapter 4 emphasized the need for teachers to help their students construct new forms of knowledge. In this sense, teachers who participated in professional development should be introduced to the why and how of teaching and learning approaches, along with strategies needed to facilitate the construction of new types of knowledge.

Therefore this study aims to support teachers’ construction of new knowledge and practice in the professional development domain. Based on the ideas of effective change processes, this study will focus on creating professional development model that emphasizes linking theory and practice, continuous support for teachers in their classroom context, and sustained contact to check teachers' progress. This study will be centered on a professional development workshop, because it can play an important role in introducing key principles of new practices and assist teachers in developing processes that will enhance knowledge and skills (Pillay, 2002). However, a one-hit workshop is insufficient to effect teacher change with respect to application of new practices. A more long-term professional development is needed to facilitate growth in practitioners (Kayler, 2003; Shield *et al.,* 1998; and Weiss *et al.,* 1998). Therefore, this study incorporates lesson study that take place within a sustained contact phase of the professional development experience. Many of the workshop activities will be designed to integrate inquiry-based instruction and encourage teacher learning about inquiry-based science teaching. This study also integrates narrative and reflective tools as effective instruments for facilitating teacher growth.

CHAPTER III

RESEARCH METHODOLOGY

Introduction

The purpose of this study was to develop and implement a professional development model designed to provide elementary teachers opportunities for constructing knowledge of science teaching and learning through inquiry and reflection in the context of Thai science education. This study was conducted using interpretive methodology. The primary methods included case study and narrative, particularly teacher cases and metaphors. A variety of data was collected as part of the case study including interviews, journals and field notes. Case study was an important method for developing a deep understanding of the impact of reflective, inquiry-based professional development. Narrative methods shed light on teachers' knowledge of learning to teach science through inquiry. This chapter presents the methodological framework of the study through discussion of the following sections: general methodology, ensuring trustworthiness in interpretive research, methods of the study, context of the study, procedures of the study, and data collection and analysis.

General Methodology

Qualitative research methods are designed to help researchers understand people, social, and cultural contexts within which they live. It uses a naturalistic approach that seeks to understand phenomena in context-specific settings where the researcher does not attempt to manipulate the phenomenon of interest (Patton, 2001).

Qualitative analysis results are a different type of knowledge from quantitative inquiry, because they are underlying in different philosophical nature of paradigm. The quantitative research is supported by the positivist or scientific paradigm which leads to regard the world as made up of observable, measurable facts (Glesne and Peshkin, 1992). It assumes that social facts have an objective reality and variables can be identified and measured. The qualitative research is classified as subjective reality supported by naturalist paradigm that is concerned with the uniqueness of each particular situation (Burrell and Morgan, 1979). Moreover, Kaplan and Maxwell (1994) argue that the goal of qualitative research is to understand a phenomenon from the point of view of the participants and its particular social context. Therefore, the methods in qualitative research are mostly "enjoying the rewards of both numbers and words" (Glesne and Peshkin, 1992). In this sense, Golafshani (2003) argues that methods like interviews and observations are dominant in the naturalist (interpretive) paradigm and supplementary in the positive paradigm, where the use of survey serves.

Interpretive Methodology

Interpretive methodology is one type of qualitative research. It starts out with the assumption that access to reality is only through social constructions such as language, consciousness and shared meanings. According to Boland (1985), interpretive studies generally attempt to understand phenomena through the meanings the people assign to them. Therefore, researchers are an important instrument, especially researcher understanding, for making sense of meaning from arguments closer to research practice.

In the study of the science education field, interpretive methodology is often used to understand, in depth, teachers or students' actions and the knowledge, beliefs, and values that lie behind. The interpretive researcher in science education was described by Gallagher (1991:7) as follows:

> Interpretive research adds a deep 'social' dimension to our methodological resources in science education. 'Social' is central to interpretive research and the methodology enriches our ability to study the social nature of science teaching. In addition, interpretive research has a central concern with the ways that persons make sense of, and give meaning to, the social interactions that constitute daily life in and around schooling, especially the discourse between teachers and students.

Because of the attempt to understand phenomena in deep social dimensions, interpretive research does not predefine dependent and independent variables, but focuses on the full complexity of human sense-making as the situation emerges (Kaplan and Maxwell, 1994).

Interpretive methodology served as the overall methodology because this study was guided by prior theoretical commitments and conceptual schemes of inquiry and reflection, and their influence on professional growth and change. This study aimed to contribute and expand the knowledge base for reflective, inquiry-based professional development. The interpretive research process usually begins with broad questions which provide a focus for data collecting. Analysis and interpretation of data provide insights into the questions, which usually are refined, and new data collection strategies are formulated until researchers get a set of assertions on what is learned of the study (Gallagher and Tobin, 1991).

The aim of this research was to investigate the effect of developing and using the professional development model for upper-elementary science teachers which focuses on teachers' understanding in inquiry teaching. Researcher as one of researcher instrument should enter to teachers' context to investigate what teachers do and why they do it that way.

Methods of the Study

This study comprised of two main methods – case study and narrative. Each of the methods involved a selection of primary and secondary data sources. Case study involved the use of interview, observation, and document analysis. Narrative involved the use of metaphor, journaling, and the development of written case reactions and classroom cases.

1. Case Study

According to Yin (1994:13), case study is a term used to describe a research process of empirical inquiry that "investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.” An outstanding characteristic of case study is its emphasis on interpretation in context. When conducting case study research, the researcher concentrates on a single phenomenon or entity to expose the interaction of significant factors characteristic of the phenomenon (Merriam, 1998). In this research, case study methods helped the researcher develop an understanding of the impact of professional development for teachers in their real-life contexts. It helped the researcher make sense of how the teachers translate the knowledge that they construct during professional development into practice. Case study was used to understand teachers’ knowledge and the contextual factors that influence teachers’ professional knowledge growth.

Case study helps in the interpreting of teacher construction of knowledge for inquiry teaching and their translating that knowledge into practice in particular context. According to Merriam (1998), case studies can be categorized three ways: (a) descriptive case study, (b) interpretive case study, and (c) evaluative case study. Descriptive case study is useful for presenting basic information to form a database for future comparison and theory building. Interpretive case study contains rich and thick description which is used to develop conceptual categories. The researcher gathers as much information about the problem as possible with the intent of analyzing, interpreting, or theorizing about the phenomenon. Evaluative case study involves description, explanation, and judgment. In this sense, the case study is evaluative “because it provides thick description, is grounded, is holistic and lifelike, simplifies data to be considered by the reader, illuminates meanings, and can communicate tacit knowledge” (Merriam, 1998: 39.)

This study used descriptive and interpretive case study. The data from the case study described what happens when a professional development model for Thai elementary science teachers is planned, translated, and experienced. Moreover these data were interpreted from the description to set the patterns of how teachers develop their knowledge of inquiry teaching.

2. Narrative Methods

The narrative methods in this study consisted of case reaction, metaphor, and teacher generated cases. In this study, narrative had both an instructional value and a research purpose. As an instructional tool, narrative methods assisted teachers in constructing new knowledge of effective teaching, building on their prior knowledge. Case reactions and metaphors were important tools for helping teachers reflect on the action of teaching. This study used narrative methods to answer the question “How does teachers’ narrative knowledge with respect to the teaching of earth science evolve during a professional development experience?”

Context of the Study

This study was conducted using interpretive methodology. The qualitative design for this study incorporated case study and narrative methods. The professional development was designed by focusing on reflection and inquiry approach. Reflection was used as a tool to help teachers develop their teaching practice. Inquiry was introduced as an approach that teachers could apply to their lesson design and to support teachers’ learning of how to teach earth science. To support inquiry experiences for teachers, the professional development experience was designed using the 5E inquiry model which consists of five steps of learning experiences: (a) engagement, (b) exploration, (c) explanation, (d) elaboration, and (e) evaluation.

1. Participants in the Study

The participants in this study consisted of four elementary science teachers who were studied as individual cases using the case study method. They worked closely with the PhD science education student, a key researcher, in this study. Moreover a science educator, an educational researcher, and a scientist served the role of advisors with the instruction of professional development. The professional development experience consisted of a workshop and modified lesson study. In the second phase of implementing the workshop, 13 science elementary teachers (including the four case study teachers) were the participants. All 13 teachers participated in the activities of professional development. However this study especially focused on the four teachers for in-depth study. Most data were collected richly from these four elementary science teachers to make sense of how they developed their knowledge and belief about teaching.

1.1 Description of the Researcher and Advisors

The researcher and advisors from Kasetsart University consisted of the Ph.D. science education student as a key researcher, two science educators, one educational researcher, and two scientists. The researcher and advisors played important roles in the design and implementation of the professional development workshop and modified lesson study. The initial reflective, inquiry-based activities were examined and adjusted by the researcher and advisors from the education department. The earth science concepts at the heart of each activity were reviewed by the advisor from the science department. During the workshop and modified lesson study, the researcher had main responsibilities for instruction and data collection. After that, data were analyzed by the researcher and checked by advisors.

1.2 Description of the Participants in Exploring Teachers' Teaching Situation and Professional Needs

The participants in the exploring phase consisted of science teachers in grades 4-6 from 50 schools of the Pathum Thani Educational Service Area 1, where present more than 10 teachers teaching in school. These 50 schools were from 3 districts of Pathum Thani Educational Service Area 1; Meaung, Klonglauang, and Lard-Lumgeaw which consists of 17 schools from Meaung, 16 schools from Klonglauang, and 7 schools from Lard-Lumgeaw. The number of selected schools was different in 3 districts because Meaung and Klonglauang are big districts while Lard-Lumgeaw is smaller. This group of teachers was chosen by "purposive sampling" in order to get the data from teachers who represent teachers graduated directly in science or science teaching fields and non-science or non-science teaching fields. They were expected to give data on questionnaires about their current situation in science teaching, problems in science teaching, and needs in professional development.

1.3 Description of Teachers Participating in the Professional Development Experience

After data collected and analyzed from the questionnaire about teachers' professional development needs, a group of grade 4, 5, and 6 teachers were selected to participate in the workshop. Thirteen teachers, including the four teachers of the case study, were selected using "purposeful sampling" which help the researcher understand the problem and the research question (Creswell, 2003) based primarily on a convenience sample which is cheap, easy, and quick (Liamputtong and Ezzy, 2005). The thirteen teachers were individuals who teach in elementary schools under educational area 1 of Pathum Thani province which covers three districts; Meaung, Klonglauang, and Lard-Lumgeaw. Based on the limitations of time, money, and the distance between each school in these three districts, teachers from two schools in Klonglauang were selected to participate in the professional development aspects of this study. The researcher obtained permission from the principals of these two schools to allow teachers participating in the professional development experience. These thirteen individuals teach grade 4 – 6 at the elementary level. Although earth science content focusing on weather and geology is taught in only grade 4 and 5, the teachers who teach in grade 6 were asked to participate in this workshop, because Thai elementary teachers always circulated the responsibility in teaching science among grade 4, 5, and 6, the grade 6 teachers were included in the professional development. These thirteen teachers attended a three-day workshop focusing on weather, rocks, minerals and soil using science reflective, inquiry-based instruction. After the workshop was over, four case study teachers participated in modified lesson study.

1.4 Description of the Members of the Case Study

The case study aspect of this research was centered on four teachers from two schools. There were two fourth grade teachers from Thamma School and two teachers were from Radbumrung School. The teachers from Radbumrung School had taught in different grade levels. One teacher taught in grade five and another teacher taught in grade six. They worked collaboratively with the researcher in modified lesson study. The researcher had the roles of both a participant observer and facilitator.

The participants in this case study were selected by "criterion sampling" which is useful for providing detailed and rich data relevant to the particular research problem (Liamputtong and Ezzy, 2005). From the larger group of 13 teachers, four participants were asked to participate in a case study teacher aspect of an extended professional development experience for this research. The criteria used to select these participants was: (a) four teachers divided in two groups of grade 4, and 5 where geology and weather are topics that are in the curriculum, (b) four teachers in the same school, and (c) four teachers who volunteer to facilitate providing rich data.

In context of Pathum Thani, there were not many teachers in the school. Either, there were not many teachers ready to voluntarily participate to provide rich data in the study. Two teachers from Thamma School were selected according to all criteria. They were teaching in the same school. They taught in grade 4 and were focusing on geology in the second semester. They volunteered to provide rich data. The other two case study teachers were not exactly selected based on the same criteria. They were from the same school and volunteered to provide rich data. They worked in different grade levels. One teacher taught in grade 5 where weather topics would be taught in second semester and another teacher taught in grade 6 which focused more on astronomy in second semester.

Setting of the Study

1. School Setting

Radbumrung School and Thamma School were elementary schools where four teachers visited during the months of November, 2006 to March, 2007. Four teachers worked closely with the key researcher in modified lesson study. The distance between two schools was around 2.5 km. The researcher had to travel between two schools during sustain contact.

1.1 Thamma School

Thamma School was a large school consisting of 1,100 students. It was an extended elementary school which contained grade levels from pre-elementary to junior high school. There had a big area containing a big sports field, health garden with many plants, and playground for students. However, this school got the small grant. The buildings were not large enough for big amount of students. There was also lack of learning media. The classroom contained 40-50 students. There was one computer room for every class rotating 3 hours/week. There was no science laboratory room and no science equipment. Science teachers had to prepare science equipment by themselves; therefore, teachers were not very focused on doing experiments. This school was surrounded by a rice field, and big market. Mostly students were from medium to poor families who worked in the rice field, factories, or as general labor.

Focusing on science learning, science subjects were taught by the classroom teachers who responsibility it was to teach all subjects for their own classroom. The case study teachers from this school were Boon and Yanee who had to teach all subjects. They did not, however, write lesson plans for all subjects. The principals allowed them to write lesson plans in only the subjects they were interested in. Boon chose to write lesson plans in evocation and technology subjects. Yanee choose to write lesson plans focusing on Thai and Mathematic subjects.

1.2 Radbumrung School

Radbumrung School was a large school where there were around 1,700 students. It was an extended elementary school the same as Thamma School, but the school environment and the learning system were different. This school had limited area and equipment. There were only buildings and the school couldn’t provide a playground, garden, or sports field for student recreation. There were around 40-50 students in one classroom. The school was surrounded by urban community such as apartments, small factories, small offices and the big market. People mostly moved in the community to work. Therefore the amount of students was increasing very fast. These students were from medium – poor families. Even though the school was big and contained many students, it was unable to buy learning media and to prepare learning resources for lessons. For example, there was only one laboratory and one computer where teachers had to rotate for only a short time a week.

Science learning in this school started in grade 1. In lower elementary (grade 1-3), the classroom teachers would teach all subjects to their students. Teachers started to separate for special subjects in upper elementary (grade 4-6). The case study teachers from this school in this study were Pim and Keaw who taught science in different grades. Pim taught science for grade 5 (3 classrooms). Keaw taught science for grade 6 (3 classrooms), was also the head who took responsibility in organizing science, and took care of laboratory room for elementary level.

2. Exploration Setting: How to Explore the Teachers' Professional Development Need?

Teachers' opinions of science teaching according to education reform and needs in professional development were surveyed through a rating-scale questionnaire. The questionnaire was distributed to 150 grade 4-6 science teachers in 50 schools in May, 2005. The respondents sent their response to the researcher by July, 2005. The questionnaire consists of four sections that were (a) background of the respondents, (b) the current situation of teaching according to educational reform, (c) opinion on professional development needs, and (d) the need for participating in professional development. The questionnaires were sent by mail. The researcher put empty envelopes with stamps included for the respondents to send the questionnaire back to the researcher. The four case study teachers of this study were also selected from the respondents of this questionnaire. They were interviewed to provide deeper information about their current teaching, confidence with science content, and problems, challenges or their professional development needs.

3. Professional Development Setting

3.1 Workshop: What Does the Professional Development Workshop Look Like?

The workshop consisted of three days of professional development which occurred during the semester break. In Thailand, the normal organizational structure of schools is based on a two-semester system. The first semester spans from May to September. The second semester spans from November to March. Many schools in Pathum Thani province teach earth science (including rocks and soils in grade 4, weather in grade 5) during the second semester. Therefore the first phase of this professional development took place after the first semester during the break in order to prepare teachers to teach earth science in the second semester. During the semester break, the participants were free from teaching responsibilities and preparing lessons for the next semester. The workshop was three-days in length in order to meet the need of allowing teachers to have some time with their family to relax outside of school.

As noted in the review of literature, short workshops like three-day workshops are not typically effective in fostering teacher learning where connections are built between what was learned and application in the real classroom setting. Short workshops are not long enough to truly develop teachers' professional growth (Kayler, 2003; Shields *et al*., 1998 and Weiss *et al.*, 1998). Therefore, this study tried to reduce this shortcoming by extending the professional growth opportunities for participants through modified lesson study held after the initial workshop.

The activities in the workshop were conducted through both individual and group work. The workshop is designed for grade 4-6 elementary teachers. The earth science concepts to be addressed were arranged in terms of "large organizing questions." The workshop used activities based on the 5E model of inquiry as a basis for fostering teachers' understanding of the concepts and how to teach them. Participants had an opportunity to reflect on inquiry-based earth science teaching.

Moreover, participants were asked to create teaching metaphors and develop written reactions to classroom cases.

3.2 Modified Lesson Study: What Does the Modified Lesson Study Looked Like?

Lesson study was used as the strategy to develop teachers' professional growth. However, this study used a modified version of the steps of lesson study so that it was appropriate for the Thai educational context. Four teachers worked collaboratively with the researcher during the modified lesson study. The lesson study technique was modified and used as a strategy for sharing ideas with respect to science content and pedagogy. The steps of the lesson study technique were the same as the original to support the number of teachers in this case study. The steps of the modified lesson study in this study included; a) planning lessons, b) observing member teaching, c) revising lesson plan, and d) re-teaching with member observation.

The modified lesson study in this study was concerned with teachers' collaborative group work. The four case study teachers were grouped into two teams. Thamma team consisted of Yanee and Boon who were the forth grade teachers. Radbumrung team consisted of Pim and Keaw who were the fifth grade teacher and the sixth grade teacher. Modified lesson study focused on the convenience of team study in the same or different research lessons. In the context of this study, teachers were from different schools and different grades, therefore, the researcher worked with two teams separately. Teachers from Thamma School teaching in grade 4 and in different classrooms studied the same lessons. The lessons of Thamma School team were about earth's surface, rocks, and soil. Teachers from Radbumrung School were teaching in the different grades, therefore, they separated their lessons of interest. Pim was interested in the water cycle. Keaw were interested in the phases of moon.

Procedures of the Study

This study consisted of three phases relevant to the research questions. The procedure in each phase can be described as follows:

1. Phase I: Exploring Teachers' Needs and Developing the Professional Development Model

The procedures of this phase involve the following:

1.1 Conduct a survey of teachers' needs with respect to professional development in science education

1.2 Analyze the survey to identify particular professional development needs

1.3 Review the literature to conceptualize ideas to guide effective design of professional development

1.4 Analyze the "Weather and Geology" content in Basic Science Curriculum from the Institute for Promotion of Teaching Science and Technology (IPST, 2003)

1.5 Synthesis relevant literature and the results of the needs assessment to inform the design of activities for the workshop and follow up

1.6 Design preliminary professional development plan and corresponding activities for the "workshop" and "modified lesson study as follow up"

1.7 Develop research tools, protocols and plans for data collection and analysis

1.8 Audit by experts in Science and Science Education for revising and refining the professional development plan

2. Phase II: Implementing the Reflective, Inquiry-based Professional Development

2.1 The Workshop "Using the 5E Inquiry for Science Learning in Elementary"

The procedures of the three day workshop consisted of selecting the participants and conducting the workshop which could be explained as follows:

2.1.1 Selecting the Participants

Thirteen teachers were asked to participate by volunteering to learn about 5E inquiry teaching in earth science. The principals of two elementary schools in Klonglauang district gave permission for teachers to join this workshop. A subset of four teachers was selected to participate in the case study from 13 teachers before participating in workshop.

2.1.2 Conducting the Workshop

The three day workshop included reflective, inquiry-based activities designed to facilitate teachers' knowledge of earth science teaching and learning. Instruction was introduced by large organizing questions that represent the content to be covered. The large organizing questions were: "What is 5E?", "Is Earth Dynamic?", "How to group rocks?", "How the clouds form?", "How weathering and erosion effect to earth?", "Why the wind blows?" Workshop instruction was conducted by a Ph.D. science education student and one scientist. Most instruction took place in a classroom.

Specific data collected during the workshop included: a) written reactions to two cases; b) audio-recorded transcriptions of four case discussions (case study group); c) initial metaphors of teacher beliefs about science teaching, learning, and teachers' roles; and d) researcher anecdotal notes.

A . The Metaphors

Metaphor was an important narrative tool in this study. All teachers were asked to reflect on their beliefs about science teaching through the first metaphor on the third day of the workshop. These metaphors were analyzed to see what their view on their teaching was while participating in the workshop. At the end of follow up, teachers were asked to write a second metaphor in order to see how they changed their knowledge base or belief in teaching. The protocols that guided the development of metaphors are in appendix A. Teachers could read examples of the teaching metaphor provided in appendix B.

B. Written Case Reactions

The two cases that were used during the professional development workshop presented dilemmas that challenged teachers to think about effective inquiry teaching. These two cases were constructed by using protocol in appendix C. The dilemmas of each case can be summarized as follows:

1) Case 1: “Too many questions, too little time” The dilemma in this case centers on the teachers’ use of questions to help students understand scientific concepts associated with the “water cycle”.

2) Case 2: “Between a rock and a hard place: Assessment dilemmas in inquiry science” The main dilemma in this case centers on the teachers’ use of authentic assessment in inquiry-based teaching. A secondary dilemma in the case focuses on students’ alternative conceptions and the role of discourse.

The teachers were asked to read the whole cases. After that they were asked to construct written reactions to the cases. The reactions developed by the four case study participants served as data for the study. Each case was described in appendix D.

2.2 Modified Lesson Study

The procedures for this phase include the following:

2.2.1 Selecting the Participants

Participants were the four case study teachers who participated in the workshop section. These participants were met after the workshop in order to expand their opportunities for growth in professional development through modified lesson study.

2.2.2 Conducting the Modified Lesson Study

Lesson study team meetings consisted of a) introducing lesson study meeting, b) planning lesson study meeting, c) designing lesson study meeting, d) meeting after teaching, and e) meeting after re-teaching.

In the modified lesson study, participants had opportunities to work in groups collaboratively with other teachers who teach in the same school. The modified lesson study took place from November to February. The procedures for conducting the modified lesson study can be explained in the following way:

A. Thamma School

Yanee and Boon met the researcher after the workshop for continued professional development. They were teaching in grade 4, therefore, they shared the same lessons. The researcher worked collaboratively with them during November, 2006 to February, 2007 for developing three lessons on geology which were about the earth’s crust, rocks, and soils.

B. Radbumrung School

Pim and Keaw met the researcher after the workshop during November, 2006 to February, 2007. They were in different grades. Pim taught in grade 5. She was interested in developing a lesson about the water cycle. Keaw was a grade 6 teacher. She was interested in developing a lesson looking at the phases of the moon. Therefore the developed lessons of these two teachers were different topics depending on the responsibility of teaching in different grades. They worked together for designing, teaching, revising, and re-teaching each lesson.

The data of modified lesson study from the four case study teachers was collected by taking note and audio taped recordings during discussion. Their teaching was video tape recorded. Following the first three meetings, after teachers had finished developing 5E inquiry-based lesson plans about geology and weather, classroom observations were conducted. The observations were focused on a teacher who was asked to implement the research lesson plan in his/her class. The observation of these four teachers happened at different times. In each observation in each team, the other teacher and the researcher observed his/her teaching. The details of the procedure for modified lesson study are included in the modified lesson study protocol in appendix E.

After these four teachers completed their teaching for the second semester in February, they were asked to write their own cases based on a dilemma encountered while implementing their lesson plans. The case writing protocol was as same as the protocol for case written in appendix C. Moreover, they were asked to write their own metaphor a second time (Appendix A).

Data Collection

The data in this study could be described as primary data and secondary data sources. The primary data sources were the important data collected from the four case study teachers. This primary data was collected by semistructured interview, semistructured journal, case reaction, written case, metaphor, and field notes. The secondary data source was teacher artifacts including curriculum documents and teachers' lesson plans. These data were analyzed by constant comparative method for developing assertion of this study about how teachers develop their knowledge and beliefs about learning and teaching earth science.

1. Interview

In addition to the narrative methods already described, phase three of the study (study of the impact on classroom practice) included teacher interviews, classroom observation and analysis of artifacts. Merriam (1998: 72) suggested that "interview is necessary when we cannot observe behavior, feelings, or how people interpret the world around them. It is also necessary to interview when we are interested in past events that are impossible to replicate." The types of interview can be distinguished based on the amount of structure they include. Three common types of interview include structured/standardized, semistructured, and unstructured/ informed interview. The characteristics of types of interview are as follow; a) the structured/ standardized interview consists of wording of questions predetermined and order of questions predetermined, similar to an oral survey; b) the unstructured/ informed interview features open-ended questions and is flexible, exploratory, and more like a conversation; c) the semistructured interview has mixed characteristics with some structured questions. Interview is an important tool for eliciting the narrative of the respondent's story.

This study used semistructured interview with more open-ended and less structured questions. The benefit of the less structured interview is that the researcher can respond to individuals in unique ways. A guided list of questions or issues to be explored (neither the exact wording nor the order of the questions is determined ahead of time) guided the interviews. This format allows the researcher to obtain information according to the issues that emerge and reflect the respondents' worldview as well as new ideas.

The semistructured interview was used only with the four teachers who participated in the case study. There was a semistructured interview conducted with each teacher. The semistructured interview helped the researcher explore the questions of interest in this study. The semistructured interview was in appendix F.

2. Observation

Obtaining information that takes place in the natural field setting is important for setting categories from data of case study. Observation is the primary method for collecting data in the field setting. According to Merriam (1998), informal interviews and conversations are often interwoven with observation. The term "field note" in this study was used to connote both activities involving observation and informal interviews. In observation, it is difficult to avoid relationships with the participants. This relationship might effect the interpretation of data. Therefore it is necessary to define the relationship between the observer and the observed in the study. There are four classical typologies used to describe the relationship between observer and observed (Merriam, 1998 cited Gold, 1958); a) complete participant, b) participant as observer, c) observer as participant, and d) complete observer. The level of relationship between observer and observed is different in each type of observation. The closest relationship in observation is when the observer is a complete participant. In this case, the observer is a member of the group being studied; however, this role should not disrupt the natural activity of the group. The participant as observer is used when the observer is known to the group, but the role of observer is subordinate. When the researcher is a participant in the designated role of observer he/she is known to the group as the information gatherer. This way, the observer can access many people to get a wide range of information, but the information might be revealed in a way that is controlled by the group members. The observer is typically hidden from the group. The data that is usually generated from this type of observation is a description of the real activity with no disruption from the observer. This study defined the role of observer as the "participant observer". This type of relationship had the advantage of enabling the researcher to develop deeper understandings. The observer got involved in the setting of the group to assume responsibilities that advance the group, but according to Adler and Adler (1994), did not participate fully in terms of members' values and goals.

The process of collecting data through observations can be broken into three stages: entry, data collection, and exit. In the entry stage, the researcher asked permission from the four teachers and from their principals to observe selected classrooms. The observations started in November after these four teachers had participated in the October workshop. The observation aims to investigate the research question: "How do teachers translate what they learn through the professional development experience into classroom practice?" The main focus of the observation was on how teachers teach inquiry lessons in their classrooms. In terms of data collection, the researcher took field notes during teachers' lessons. Some informal interviews with teachers may be needed for a deeper understanding of each observation. The data collection was continued until the researcher obtained enough information for setting the assertion of how teachers teach science by inquiry. This stage means that the researcher can exit from the observation. These observations took place at the same time as observations of the modified lesson study. The field notes also focused on the questions for observations that the teacher team set during modified lesson study. Each case study teacher was observed at least once during the semester.

3. Case Reaction

When reading, discussing and writing reactions to cases, teachers analyzed their own conceptions of effective teaching. Moreover, according to Kobella and Tippins (2002) teachers' ability to solve problems and make decisions is also developed by this process. In this study 13 teachers were asked to read, discuss, and write reactions to two written cases during the workshop. The two cases were about teaching/learning dilemmas concerning weather. These cases contained different dilemmas that challenge teachers to think about how to teach inquiry-based earth science for elementary students. Teachers were asked to construct written reactions to these cases as part of their professional development during the workshop. The teachers were assigned to read, reflect (discuss) and write reaction to each case in workshop for 15-30 minutes. The four teachers who participated in the case study aspect of this research were audio-recorded during class discussion and transcribed. After the modified lesson study of the professional development, the four teachers' participating in the case study identified a dilemma in their own teaching. They constructed a case which was used as a centerpiece for reflection.

4. Metaphor

Metaphor in language may reveal patterns of thought in individuals and in groups (Cameron and Low, 1999). This study used metaphors to explore teachers' knowledge (beliefs) about science teaching and learning.

Teachers were introduced to the idea of metaphor as a way to conceptualize their beliefs about teaching and learning during the workshop. Thirteen teachers were asked to write their own metaphors. Each teacher constructed a metaphor to represent their personal beliefs about science teaching and learning. Their initial metaphors were developed on the first day of the workshop. These metaphors were used to explore what teachers think about their teaching roles and philosophy of science teaching and learning. Later, teachers were asked to re-visit and write a second metaphor after participating in the modified lesson study. This time, metaphors were analyzed to explore how patterns of thought about teachers' roles and belief in science teaching may change. The metaphors that were developed by the four case study teachers served as data for this study.

5. Journal

Journaling was the final narrative tool that was used in this study. There are many uses of journals for different purposes. Some examples are: (a) to gather personal experiences about specific teaching incidents as a stimulus for class discussions, (b) to explore the development of personal identity, and (c) to explore the beliefs held by teachers (Williamson, 2003.) In this study, journals were developed by the four teachers. The journals were used to explore the professional knowledge growth of teachers. Teachers were provided with semistructured journal questions focused on the teaching of earth science in the classroom. Teachers kept the journals during the sustained contact portion of the professional development, in order to study impact on classroom practice. The semistructured journal protocol was in appendix G.

6. Teachers' Artifacts

There were many documents that provided useful information in this study. Teachers' lesson plans and revised lessons were the main archival documents that the researcher collected from teachers during modified lesson study. Moreover, the data from IPST science curriculum and textbooks were collected as information to consider in designing the reflective, inquiry-based professional development model.

Data Analysis

The processes in data analysis in this study consisted of processes that were coding, categorizing data, and memo-writing. These processes are referred to as the constant comparative method of data analysis (Merriam, 1998). According to these processes, all data was compared to find the codes. The same set of coded data was put together and distinguished from another code set. These comparisons lead to tentative categories. The comparisons include data with data, category with category and concept with concept.

1. Coding and Categorizing the Data

The process of coding was conducted by open coding, axial coding, and selective coding. In constant comparative analysis, coding is important for raising conceptual categories. Charmaz (1994: 83) described coding and conceptual categories, noting that "code means a label applied to certain data; a code remains less abstract than a conceptual category. In turn, a conceptual category is part of the researcher's larger theoretical framework in which he or she specifies conditions, offers explanations, and makes predictions."

Strauss and Corbin (2002) explained the definition of open coding, axial coding, and selective coding as follows: (a) open coding is "the analytic process through which concepts are identified and their properties and dimensions are discovered in data" (p. 101); (b) axial coding is "the process of relating categories to their subcategories, termed 'axial' because coding occurs around the axis of a category, linking categories at the level of properties and dimensions" (p. 123); and (c) selective coding is "the process of integrating and refining the theory" (p. 143).

1.1 Open Coding

Several different ways of conducting open coding were described by Strauss and Corbin (2002). "Line-by-line analysis" is the form of coding that involves close examination of data, phrase by phrase and sometimes word by word. Line-by-line coding can enable the analyst to generate categories quickly. Another way to begin coding is "writing code notes". The analyst writes down the concepts in the margins or on cards as they emerge during analysis.

1.2 Axial Coding

Axial coding is the act of relating categories to subcategories along the lines of their properties and dimensions (Strauss and Corbin, 2002). This type of coding can help the analyst to look at how categories crosscut and link. Strauss and Corbin (2002) suggested that a major focus of axial coding is to see how categories relate and link.

1.3 Selective Coding

Selective coding is the process of integrating and refining categories (Strauss and Corbin, 2002). This process involves a central category (core category) which represents a main theme of the research. Strauss (1987: 36) provided a list of criteria for choosing a central category including:

- It must be central; that is, all other major categories can be related to it.

- It must appear frequently in the data. This means that within all or almost all cases, there are indicators pointing to that concept.

- The explanation that evolves by relating the categories is logical and consistent. There is no forcing of data.

- The name or phrase used to describe the central category should be sufficiently abstract that it can be used to do research in other substantive areas, leading to the development of a more general theory.

- As the concept is refined analytically through integration with other concepts, the theory grows in depth and explanatory power.

- The concept is able to explain variation as well as the main point made by the data; that is, when conditions vary, the explanation still holds, although the way in which a phenomenon is expressed might look somewhat different. One also should be able to explain contradictory or alternative cases in terms of the central idea.

1.4 Memo-writing

Memo-writing is used for breaking categories into components and elaborating codes. Researchers used memo-writing to move from the data to analysis. Using memos, data is systematically examined to make early codes. Charmaz (1994: 85) described the process through memo-writing as one where "the researcher takes his or her emerging ideas apart, checks them, and outlines further data collection. During each stage of memo-writing, the researcher may use his or her theoretical background to deepen the analytic insights." Memos represent the development of codes from which they are derived. Strauss and Corbin (2002: 110) explained the definition of memo as "the researcher's record of analysis, thoughts, interpretations, questions, and directions for further data collection." According to Charmaz (1994), memo is an intermediate step between coding and writing the first draft of the analysis. Memo writing is used to connect the barebones, analytic framework that coding provides with the polished ideas developed in the finished draft. By making memos systematically while coding, the researcher fills out and builds the categories. Thus, the researcher constructs the form and substance toward a finished piece of work and develops the depth and scope of the materials.

1.5 Concept Formation and Development

After deriving a central category, a tentative conceptual framework was generated using the data as reference. Further development of a concept involved three major steps necessary to serve the expansion of emerging theory. These three steps were reduction, selective sampling of the literature, and selective sampling of the data (Stern, 1994). In the "reduction" step, the category is compared with another category to see how they cluster or connect. Reduction was the first step in discovering the 'clustering categories' which helped the analyst see how everything fit together. In "selective sample of the literature", existing literature was woven into the existing of data, categories, and conceptualization. These two steps were an inductive process of searching the clues. The third step was "sampling of data" which served as a deductive process to form the verification of the study. The selective sample of the literature was a step needed for comparing the data to determine under what conditions they were likely to occur. More data might be collected at this time in a selective manner for the specific purpose of identifying the properties of the main categories or variables.

The data collection stopped at this step when the researcher found out that there was a saturation of the categories. At this point, data were collected regarding a category until the analyst was satisfied that no new information was being received.

1.6 Concept Modification and Integration

This step involved the two processes of memo writing and theoretical coding. Through these processes the assertions were finally integrated and delimited. Stern (1994) suggested that in the process of concept modification and integration, the analyst compared their concepts with more highly developed concepts to discover the relationship, and once again, related concepts were compared with data for validation. The comparative analysis method was the most important method in this step, as analysts usually made a matrix of analysis.

In this study, the primary data sources that were collected from the four case study teachers were brought to the process of coding, categorizing, and memo writing after collecting each data. All primary data consisted of semistructured interview, semistructured journal, case reaction, written case, metaphor, and field notes which were coded and categorized.

In the coding process, the coded data were compared with other data and assigned to clusters or categories according to obvious fit (Stern, 1994). The researcher used ‘open coding’ as the first step to identify the properties or dimensions of conception from data and group those conceptions into categories. After that, all categories were divided according to their subcategories and a comparison of these categories was made to find the relationship in ‘axial coding.’ In this level of coding, the researcher developed linking categories at the level of properties and dimensions from subcategories. The related categories were integrated as cluster categories in the process of ‘selective coding.’ This time the researcher could refine the tentative conceptual framework. During the process of coding and categorizing, the researcher used memo-writing to help with moving the data to analysis. The researcher used ideas and theoretical background for deepening the analytic insights. When the data from each of the four teachers were open coded separately, these data could be compared in the analytical process of axial coding by comparing data with data which means: (1) comparing different people’s situations, beliefs, behavior or accounts of the same type of event or issue, (2) comparing data from the same people at different times and (3) comparing properties found in the data with other properties. Through this analytic process, the researcher got the first draft of analysis to prepare the concept formation.

In this process, the theories from literature were taken into account. This inductive process helped the researchers to develop tentative conceptual frameworks for further conceptualization. After that, the researcher found more clues to explain the tentative conceptual framework in actual situations. This aspect of the sampling of data involved a deductive process of verification of the study. The researcher could arrive at an emergent theory when the categories were saturated and satisfied.

2. Ensuring Quality in Qualitative Research

Healy and Perry (2000) asserted that the quality of a study in each paradigm should be judged by its own paradigm's terms. Quality of quantitative research depends on reliability and validity which are tools of an essentially positivist epistemology. Joppe (2000:1) defined reliability as

> … The extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable

Based on Joppe (2000:1), reliability is the idea of replicability or repeatability of results or observations. Moreover he provides the explanation of what validity is in quantitative research:

> Validity determines whether the research truly measures that which it was intended to measure or how truthful the research results are. In other words, does the research instrument allow you to hit "the bull's eye" of your research object? Researchers generally determine validity by asking a series of questions, and will often look for the answers in the research of others.

From these citations, definitions of reliability and validity in quantitative research reveal two strands. Firstly, with regards to reliability, whether the result is replicable. Secondly, with regards to validity, whether the means of measurement are accurate and whether they are actually measuring what they are intended to measure.

However, the concepts of reliability and validity in quantitative research are viewed differently by qualitative researchers. The question of replicability in the results does not concern qualitative researchers (Glesne and Peshkin, 1992), but they are more concerned with trustworthiness (Lincoln and Guba, 1985) to provide the lenses of evaluating the findings of a qualitative research. In qualitative paradigms the terms Credibility, Confirmability, Dependability, and Transferability are essential criteria for the evaluation the trustworthiness of qualitative research.

Trustworthiness of the findings was achieved via the criterion of credibility, dependability, confirmability, and transferability. According to Lincoln and Guba (1985) and Padgett (1998), Credibility involving the results of qualitative research are credible or believable from the perspective of the participant in the research. Dependability is based on the assumption of replicability or repeatability which qualitative research couldn't measure the same thing twice. Confirmability assumed that the results could be confirmed or corroborated by others. Transferability refers to the degree to which the results of qualitative research can be generalized or transferred to other context or setting. From a qualitative perspective is primarily the responsibility of the one doing the generalizing. The researcher can enhance transferability by doing a thing description of the research context and the assumptions that were central to the research.

Credibility of this research was achieved by the techniques of triangulation, persistent observation, and member checks (Lincoln and Guba, 1985). Triangulation in this study referred to the use of multiple data collection methods and multiple data sources. Persistent observation referred to the thick descriptions obtained by the researcher observing within the environment of interaction between teacher, researcher and students. By being available and visible in the schools across a period of time, the researcher became known to the teachers and students who more freely displayed their actions. Dependability and confirmability of the data occurred through an independent audit process of the research by educational experts and scientists. The Transferability of this research was provided by thick description of the research context and the assumptions which could sensible for the person to transfer the results to a different context.

CHAPTER IV

EXPLORING AND DEVELOPING A REFLECTIVE, INQUIRY-BASED PROFESSIONAL DEVELOPMENT MODEL

Introduction

This chapter presents the process of developing the professional development model. In order to develop the professional development model of this study, the ideas of effective professional development models were gathered from reviewing literature. The teachers' needs were also determined as a part of the professional development model. Teacher experiences of this professional development model were designed based on the guiding principles, teachers' professional development needs, and teachers' current teaching situations concerning Thai educational reform. The processes of designing the research interventions are represented in figure 4.1. In order to answer the two research questions, this chapter is divided into three sections. The first section is about the guiding principles of reflection and inquiry for developing the professional development model. The second section shows the teachers' professional development needs and their current teaching situations which were incorporated in developing the professional development model. The last section describes the construction of the professional development model.

Guiding Principles for Professional Development Model

This section involves the processes of conceptualizing the in-service teacher professional development model, focusing on inquiry/reflection for earth science instruction. According to figure 1.4, several pieces of literature about Thai educational reform and science standards documents, teacher knowledge in the context of professional development for elementary science teachers, inquiry approaches to teacher development, reflective approaches to teacher development, and professional growth and teacher change were reviewed for setting guiding principles of the professional development model. This literature appears as follows:

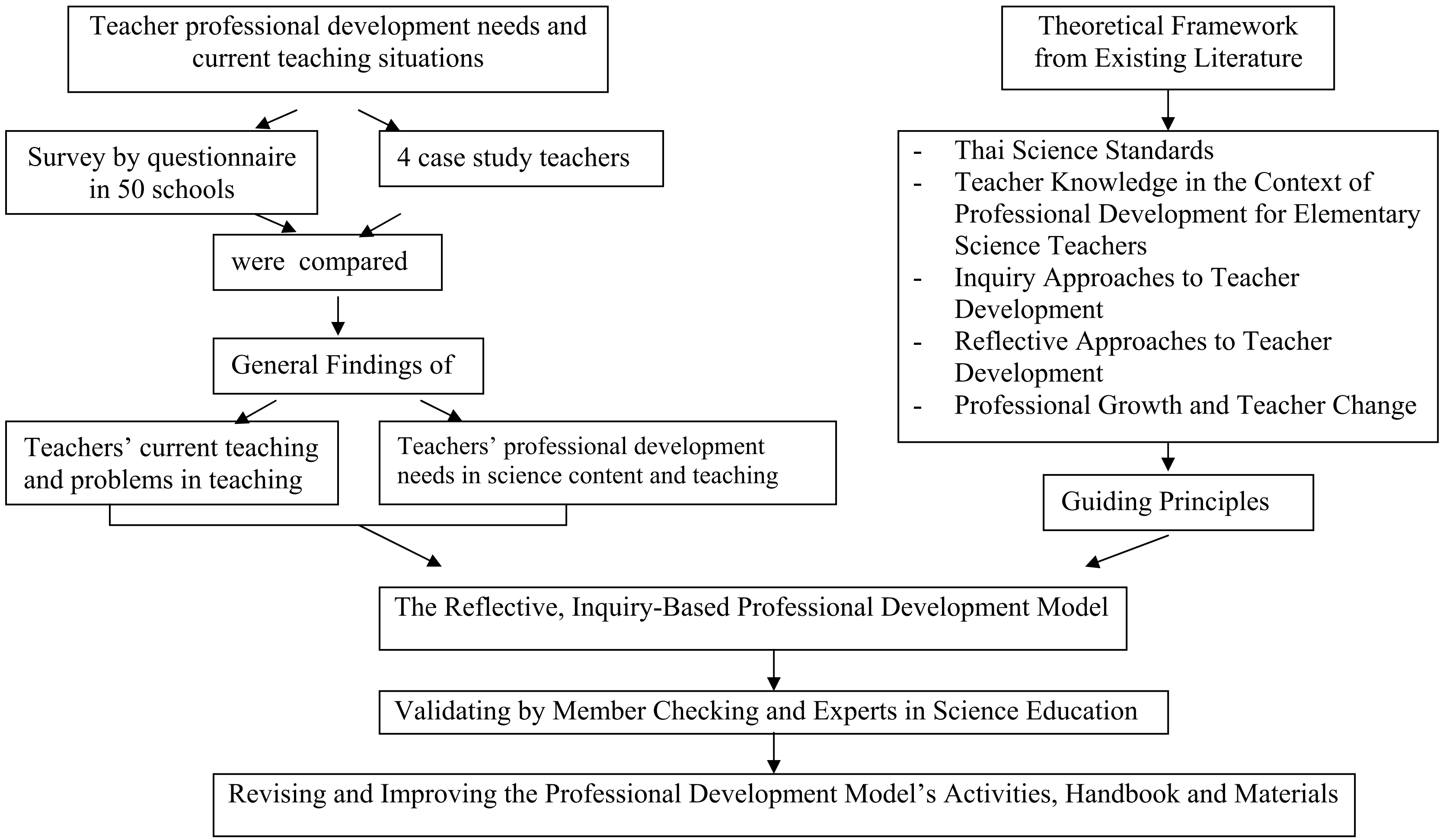

Figure 4.1 Diagram of Construction Procedure of the Reflective, Inquiry-based Professional Development Model

1. Teachers as Learners: The Learner-Centered Approach

According to the National Education Act B.E. 2542 (1999) and Amendments, the teaching and learning process aims to "enable learners to develop themselves at their own pace and to the best of their potential" (ONEC, 2002: 10). Therefore the organizing of learning should be relevant to the learner-centered approach. Teachers are concerned as the facilitators who organize the contents, activities, learning media and resources by focusing students' interests, abilities, and differentiations (Educational Reform Center, 2002).

The new vision of science teaching and learning based on the national science curriculum standards developed by the Institute for the Promotion of Teaching Science and Technology (IPST, 2003: 3), is one in which all students engage in inquiry which explained as follows:

> Students should also be curious and eager to learn about the surrounding natural world, be determined and happy about doing research and searching for knowledge, be capable of accumulating data, analyzing results to reach to answers fro questions, making decision based on reasonable use of data and finally communicating questions, answers, data and discoveries from their learning to others.

To achieve this vision teachers need new knowledge, skills, behaviors and dispositions to create the inquiry learning environments for their students. It is important for teachers to realize that inquiry learning should enable all students to learn science to the best of their potential. Therefore, teachers need opportunities to learn and inquire into science questions and reflect on their own learning and teaching in supportive learning communities and student-centered environment.

2. Teachers as Reflective Practitioners

Many scholars suggested that the reflective thinking process is very beneficial for professional development, especially, in linking theory (Ferraro, 2000) and describing teachers' tacit knowledge implicitly in action (Schon, 1987). This study emphasized both teachers' self-reflection and reflection with others (Brockbank *et al.,* 2002) which help prevent teachers' self delusion and exchanging different perspectives among teachers. In this sense, narrative in a collaborative group was the most important activity. Narrative tools such as case-based pedagogy and metaphor were introduced to stimulate reflection on what teachers know, which could involve teachers' knowledge and beliefs (Tippins *et al.*, 2002). In case-based pedagogy discussion, teachers are the persons who actively construct meaning from their prior experiences and practices connecting to the dialogue centered in case-based pedagogy. In metaphor, teachers show their tacit knowledge or belief about teaching that they held. In this study, the instructor responded on inventing case-based pedagogy and acted as a facilitator to encourage teachers engaging in the reflection of activities such as (a) expressing their metaphor of teaching, (b) discussing specific issues from case-based pedagogy or metaphor, and (c) creating their own classroom case that reflects teachers' practices in the classroom.

3. Teachers Constructing Knowledge through Inquiry Processes

This study contained two types of inquiry for supporting teachers in constructing their own knowledge. The first is narrative as inquiry (Connelly and Clandinin, 1990) and the second is the 5E instructional model (Bybee *et al.*, 2006). In the sense of narrative as an inquiry process, teachers are seeking ways to interpret the experiences, practices, or events in order to gain practical knowledge about a situation. (Connelly and Clandinin, 1990; Carter and Doyle, 1996). From the view of teachers as holders of practical knowledge, narrative as inquiry serves the role of helping teachers bring their reflections on experience and practice to construct teacher knowledge. Therefore, this study used the narrative process to help teachers interpret what they know. As explained in the second guiding principle, the narrative process was conducted with a reflective process to reveal and construct teacher knowledge.

The 5E instructional model was brought to the workshop as a process for teachers constructing knowledge in earth science. Moreover, it was expected that teachers can develop the understanding of how inquiry learning looked like through their experience in the 5E instructional model. This study was concerned with social constructivism (Vygotsky, 1949) to base the activities in the 5E inquiry on. Teachers who participated in this workshop were forced to work collaboratively in small groups. They learned and constructed earth science knowledge through group work in each step of the 5E model. They built their own understanding of new ideas connected to their prior knowledge and response to social interactions. Group work was confronted with problems or discrepant events to support teachers acquiring and organizing their own experiences. The five processes of the 5E instructional model of this study were:

3.1 engagement – the activities were designed to engage teachers in the learning task. The teachers mentally focused on an object, problem, situation, or event. The activities of this phase made connections with past experiences, exposed teachers' misconceptions, and served to mitigate cognitive disequilibrium.

3.2 exploration – the activities were designed to encourage teachers to investigate a particular topic.

3.3 explanation – teachers were asked to consider what they believed they have learned from examining the content of their exploration.

3.4 elaboration – teachers discovered the inadequacies of what they have learned, reconsidered their invented rules and modified them, so that they had general applications.

3.5 evaluation – the varieties of assessment tools and self evaluating opportunities were designed for enhancing teachers to use the skills they have acquired and evaluate their understanding.

During 5E instruction, the instructor served the role as a facilitator in every step to encourage, guide, and supported teachers' learning throughout five steps of inquiry. Moreover, at the end of the class, teachers were asked to analyze and discuss the roles of the instructor and participants in each steps of the 5E instructional model. From this discussion it was intended that teachers clarify their understanding in organizing inquiry learning through 5E instruction. They can then adapt this model to their own classrooms.

4. Integrating Elements of Teacher Change and Growth

Literature indicates that there are many elements that should be of concern in supporting a teachers change and growth. The elements for inducing change and growth are: (a) teachers learning new ideas in real situations (Radford, 1998), (b) teachers inquiry to construct the understanding of new ideas (Fullan, 1993), (c) committing teachers to practice new ideas after some short training (Dass, 2001; Luft, 2001; Radford, 1998), (d) emphasizing on specific needs of teachers (Luft, 2001), (e) evaluating teachers' effectiveness of new practices in the context of their own teaching situations (Dass, 2001), (f) team-building as an extension of new ideas to practice in school (Fullan, 1993), and (g) facilitators along with opportunities for training and for retreats (Fullan, 1993). According to these elements of teachers' change and growth in inquiry teaching, this study introduced workshop and lesson study as the main models for teachers learning and sustaining their change and growth of this professional development.

This study was designed with a one-hit workshop in order to introduce teachers to the new ideas of inquiry for supporting student learning. They had the opportunity to experience inquiry learning through 5E instruction on earth science topics. They constructed science knowledge through the five steps of inquiry. The activities were designed with concern placed on teachers' needs in order to support their learning fully. In addition, they constructed teacher knowledge through narrative and reflective processes during participation in case-based pedagogy and creating metaphors. From the workshop, teachers became familiar with the new ideas and practices in inquiry teaching and learning.

This study dealt with all elements of change and growth which are needed to facilitate advancement in teachers as practitioners. Lesson study was brought as a sustained method for practicing new ideas after the short workshop. The teachers worked in lesson study teams for planning and implementation of the 5E instruction in their classrooms. During lesson study, teachers were asked to work collaboratively for inquiry of teaching knowledge. The researcher served as lesson study facilitator to guide the process of lesson study and assist the design of 5E instruction in the team. Along with the lesson study, teachers were evaluated by colleagues and themselves for the effectiveness of inquiry teaching as a new practice in their classrooms.

Teachers' Needs and Their Current Teaching Situation

The researcher explored teachers' opinions about their needs in professional development in order to answer the research question: "What are Thai elementary science teachers' professional development needs?" Moreover, the researcher also surveyed the teachers' opinions about their current science teaching as additional information to design the effective professional development model which responds to teachers' needs in professional development and some weak points of their current teaching. The questionnaires were distributed to science teachers in grades 4-6 in 50 schools in the Pathum Thani Educational Service Area 1. Additionally, the research found out more details about professional needs and current teaching situations by interviewing four teachers who were chosen from 2 of the 50 schools responding to the questionnaire.

1. Teachers' Professional Development Needs and Current Teaching from Questionnaire

1.1 The Objectives of Questionnaire

1.1.1 Survey grade 4-6 elementary science teachers in the Pathum Thani Educational Service Area 1 about science teaching and learning according to the educational reform

1.1.2 Survey teachers' professional development needs to enhance science teaching in elementary level

1.2 Hypotheses

This questionnaire was designed to survey teachers' opinions on their teaching practices according to the educational reform. Moreover it was used to explore the teachers' professional needs in order to improve their science teaching practices. Two study hypotheses were established as follows.

1.2.1 The opinions dealing with teaching practices of grade 4-6 elementary science teachers in the Pathum Thani Educational Service Area 1 are relevant to the educational reform focusing on (a) science curriculum development, (b) lesson introduction, (c) activities in science lessons, (d) use of media and resources, and (e) assessment and evaluation.

1.2.2 Teachers have professional development needs for science content, learning activities, lesson plan writing, media and resources for student learning, and collaboration with peers.

1.3 Definition of Factors

1.3.1 The opinions dealing with teaching practices stage is the level of needs assessment of teaching performance from grade 4-6 science teachers who assess their teaching practices on (a) science curriculum development, (b) lesson introduction, (c) activities in science lesson, (d) use of media and sources, and (e) assessment and evaluation

1.3.2 The professional development needs stage is the level of needs assessment of desires or necessary conditions for successful science teaching from grade 4-6 science teachers who are primarily expected to practice on science content, learning activities, lesson plan writing, media and resources for student learning, and collaboration with peers.

1.4 Population

Grade 4-6 elementary science teachers in the Pathum Thani Educational Service Area 1 from 105 schools

Sampling

Grade 4-6 elementary science teachers in the Pathum Thani Educational Service Area 1 from 50 schools by purposive sampling

1.5 Tool

A questionnaire consisted of 4 sections: (a) background of the participants, (b) opinion on teaching, specifically science teaching and learning with regards to educational reform, (c) opinion on professional development needs, and (d) the needs for participating in professional development. In the first section, the responders checked and completed their background in the provided lists or spaces. In the second section, the responders chose their opinion on the level of relevancy between practice and reform on a provided six level rating scales: most, more, moderate, less, least, and never. In the third section, the responders chose their opinion on the level of their professional development needs using a provided four level rating scales: strongly agree, agree, disagree, and strongly disagree. The last section, the responders chose their opinion on the level of their needs to participate in professional development using a provided four level rating scales: most, more, less, and least.

The content of this questionnaire was developed by the researcher analyzing documents about educational reform. The guideline for teaching practice relevant to educational reform was discussed and proven with 2 educators. After developing the questionnaire, it was tried out on three science elementary teachers and six doctoral science education students to validate before implementing.

1.6 Data Collection

The 150 questionnaires were distributed to grade 4-6 science teachers in 50 sampling schools on May, 2005 by mail. The 95 responded questionnaires were returned to the researcher in July, 2005. This was 63.33 % of all questionnaires mailed out.

1.7 Data Analysis

The data were analyzed by means of percentages, chi-squares, and content analysis.

1.8 The Results

1.8.1 Background of the Participants

The data showed that the most responders were female (66.67%). Teaching experience of the responders could be divided into three ranges: (a) less than 3 years experience was 30.53%, (b) between 3-10 years experience was 38.95%, and (c) more than 10 years experience was 28.42%. Most of the responders graduated in non-science fields, around 81.05%. The rest of the responders graduated in science or science teaching fields (18.95%). There was 47.37 % of the responders who were experienced in participating in professional development during three years (2002-2005). Professional development topics included science teaching technique, science lesson planning, science curriculum, science projects, developing animated media, integrating subject teaching, remote learning, and analytical thinking for student learning.

1.8.2 Opinion on Teaching according to Science Teaching and Learning of Educational Reform

Tables 4.1-4.5 show the details of teachers' opinions on their teaching practices according to science teaching and learning of educational reform

Table 4.1 Teachers' opinions on the relevance between their practice and educational reform focusing on science curriculum development

(n = 95)

Science Curriculum Development	Level of relevance between practice and reform (Percent)						χ^2	df
	most	more	moderate	less	least	never		
Expressing science content correctly to the core curriculum	6 (6.3)	48 (50.5)	39 (41.1)	1 (1.1)	1 (1.1)	0	108.32*	4
Expressing updated science content	6 (6.3)	45 (47.4)	41 (43.2)	2 (2.1)	1 (1.1)	0	102.21*	4
Analyzing core curriculum	9 (9.5)	29 (30.5)	51 (53.7)	4 (4.2)	0	2 (2.1)	91.47*	4
Design lesson plan for each lesson	12 (12.6)	36 (37.9)	34 (35.8)	10 (10.5)	1 (1.1)	2 (2.1)	75.59*	5

Remark: * significant 0.05 and the underline number is the highest percent in each topic

In Table 4.1, teachers thought that their teaching practice was relevant to the instructional reform in more and moderate levels. There was 50.5 % of the teachers could express science content correctly to the core curriculum in the more level at the .05 level of significance. Focusing on expressing update science content, there was 47.4% of the teachers could do in the more level at the .05 level of significance. Teachers about 37.9% could design lesson plans for each lesson in the more level at the .05 level of significance. It was only the practice in analyzing core curriculum in which 53.7% of the teachers identified that they could do in the moderate level at the .05 level of significance.

Table 4.2 Teachers' opinions on the relevance between their practice and instructional reform focusing on introduction of science instruction

(n = 95)

Introduction of Science Instruction	Level of relevance between practice and reform (Percent)						χ^2	df
	most	more	moderate	less	least	never		
Engage students' interesting or curiosity	3 (3.2)	38 (40.0)	46 (48.4)	7 (7.4)	0	0	59.96*	3
Choose the appropriate activity for engaging students	4 (4.2)	41 (43.2)	44 (46.3)	6 (6.3)	0	0	59.48*	3
Introduction is consistently with students' prior experience	7 (7.4)	55 (57.9)	31 (32.6)	2 (2.1)	0	0	75.06*	3
Tell students to understand the objectives of the lesson	11 (11.6)	43 (45.3)	34 (35.8)	6 (6.3)	1 (1.1)	0	71.47*	4
Consider students' readiness before class	10 (10.5)	45 (47.4)	36 (37.9)	3 (3.2)	1 (1.1)	0	85.58*	4

Remark: * significant 0.05 and the underline number is the highest percent in each topic

In Table 4.2, teachers thought that they could practice relevantly to the instructional reform in the more and moderate levels for the introducing of science instruction. There was 57.9% of the teachers could introduce the instruction consistently with students' prior experience in the more level at the .05 level of significance. Teachers about 45.3% could tell students to understand the objectives of the lesson in the more level at the .05 level of significance. Teachers about 47.4% of the teachers could consider students' readiness before class in the more level at the .05 level of significance. There were two teaching practices in this topic area where teachers thought that they practiced in moderate levels. There was 48.4% of the teachers could engage students' interests or curiosity in the moderate level at the .05 level of significance. Teachers about 46.3% of the teachers could choose the appropriate activity for engaging students in the moderate level at the .05 level of significance.

Table 4.3 Teachers' opinions on the relevance between their practice and instructional reform focusing on teaching practice

(n = 95)

Teaching Practice	Level of relevance between practice and reform (Percent)						χ^2	df
	most	more	moderate	less	least	never		
Teaching is consequently and consistently with expected outcome	7 (7.4)	52 (54.2)	32 (33.7)	4 (4.2)	0	0	64.70*	3
Choose teaching technique and activities appropriate to content	10 (10.5)	49 (51.6)	32 (33.7)	3 (3.2)	0	0	56.38*	3
Teaching is consistently with students, time, and classroom condition	8 (8.4)	49 (51.6)	34 (35.8)	3 (3.2)	1 (1.1)	0	96.10*	4
Adjust activities if conditions change	10 (10.5)	61 (64.2)	20 (21.1)	3 (3.2)	1 (1.1)	0	127.68*	4
Give chance to all students join for their own learning	13 (13.7)	54 (56.8)	26 (27.4)	1 (1.1)	1 (1.1)	0	103.05*	4
Set classroom condition to support student learning	4 (4.2)	27 (28.4)	55 (57.9)	8 (8.4)	0	0	69.15*	3
Using variety activities in each lesson	3 (3.2)	32 (33.7)	56 (58.9)	2 (2.1)	0	0	86.48*	3
Using inquiry activities	8 (8.4)	36 (37.9)	47 (49.5)	3 (3.2)	1 (1.1)	0	93.37*	4
Using problem solving activities	5 (5.3)	40 (42.1)	45 (47.4)	5 (5.3)	0	0	59.47*	3
Using hands-on and mind-on focusing experiment	5 (5.3)	29 (30.5)	51 (53.7)	8 (8.4)	1 (1.1)	0	93.87*	4
Using discussion	6 (6.3)	35 (36.8)	46 (48.4)	8 (8.4)	0	0	49.88*	3
Using other learning activities (Identify….)	1 (1.1)	11 (11.6)	15 (15.8)	3 (3.2)	1 (1.1)	0	26.85*	4
Connect students' knowledge to their real life	10 (10.5)	49 (51.6)	29 (30.9)	0	0	0	25.93*	2
Develop Nature of Science during science instruction	13 (13.7)	34 (35.8)	29 (30.5)	2 (2.1)	2 (2.1)	0	55.87*	4

Remark: * significant 0.05 and the underline number is the highest percent in each topic

In Table 4.3, most of the teachers' opinions on their teaching practices were relevant to the instructional reform in the more and moderate levels. There was 54.2% of the teachers thought that their teaching is consequently and consistently within expected outcomes in the more level at the .05 level of significance. Focusing on choosing teaching techniques and activities appropriate to content, 51.6% of the teachers could do in the more level at the .05 level of significance. 51.6% of the teachers thought that their teaching was consistent with students, time, and classroom conditions in the more level at the .05 level of significance. The most of teachers (64.2%) could adjust activities if conditions changed in the more level at the .05 level of significance. Teachers about 56.8% of the teachers gave chances for all students to join for their own learning in the more level at the .05 level of significance. Moreover, 51.6% of the teachers could connect students' knowledge to their real life in the more level at the .05 level of significance. Only 35.8% of the teachers tried to develop the nature of science during science instruction in the more level at the .05 level of significance.

Moreover, there were seven lists of teaching practices relevant to the instructional reform in the moderate level presenting in Table 4.3. Teachers about 57.9% could set classroom conditions to support student learning in the moderate level at the .05 level of significance. Teachers about 58.9% used a variety of activities in each lesson in the moderate level at the .05 level of significance. Teachers about 49.5% used inquiry activities in the moderate level at the .05 level of significance. Teachers about 47.4% used problem solving activities in the moderate level at the .05 level of significance. Teachers about 53.7% used hands-on and mind-on focusing experiments in the moderate level at the .05 level of significance. Teachers 48.4% used discussions for student learning in the moderate level at the .05 level of significance. Besides these teaching activities, teachers identified other activities such as reading news, science quizzes, games, science projects, field trips, and searching information from internet

Table 4.4 Teachers' opinions on the relevance between their practice and instructional reform focusing on instructional media and learning resources

(n = 95)

Instructional Media and Learning Resources	Level of relevance between practice and reform (Percent)						χ^2	df
	Most	More	moderate	less	least	never		
Books	15 (15.8)	54 (56.8)	22 (23.2)	2 (2.1)	1 (1.1)	0	99.08*	4
Instant activity set	4 (4.2)	20 (21.1)	34 (35.8)	23 (24.2)	9 (9.5)	2 (2.1)	50.56*	5
Material and Local Media	7 (7.4)	38 (40.0)	34 (35.8)	14 (14.7)	1 (1.1)	0	57.38*	4
Invented media by teacher	5 (5.3)	15 (15.8)	49 (51.6)	20 (21.1)	3 (3.2)	1 (1.1)	104.48*	5
Laboratory	8 (8.4)	28 (29.5)	37 (38.9)	17 (17.9)	2 (2.1)	3 (3.2)	64.09*	5
Library	5 (5.3)	22 (23.2)	51 (53.7)	12 (12.6)	3 (3.2)	2 (2.1)	111.34*	5
Expert	0	5 (5.3)	12 (12.6)	31 (32.6)	15 (15.8)	32 (33.7)	30.21*	4
Learning Resources in Local	8 (8.4)	14 (14.7)	38 (40.0)	21 (22.1)	10 (10.5)	3 (3.2)	49.87*	5

Remark: * significant 0.05 and the underline number is the highest percent in each topic

In Table 4.4, the results showed that teachers were concerned with teaching by following text book. Mostly of teachers (56.8%) used books in the more level at the .05 level of significance. There was 40% of the teachers used material and local media in the more level at the .05 level of significance. Most teachers were moderate in using a variety of learning media and resources. There was 53.7% of the teachers used the library in the moderate level at the .05 level of significance. Teachers about 51.6% used their own invented media in the moderate level at the .05 level of significance. Some teachers (40%) used local resources in the moderate level at the .05 level of significance. Teachers about 38.9% used laboratories in the moderate level at the .05 level of significance. Teachers about 35.8% of the teachers used instant activity sets in the moderate level at the .05 level of significance. There was 33.7% of the teachers who had never asked help from a local expert to provide knowledge for students.

Table 4.5 Teachers' opinions on the relevance between their practice and instructional reform focusing on evaluation

(n = 95)

Evaluation	Level of relevance between practice and reform (Percent)						χ^2	df
	most	more	moderate	less	least	never		
Measure and Evaluate consistently with objectives	9 (9.5)	<u>54</u> <u>(56.8)</u>	29 (30.5)	2 (2.1)	1 (1.1)	0	99.08*	4
Measure and Evaluate consistently with content, time, and students	5 (5.3)	42 (44.2)	<u>46</u> <u>(48.4)</u>	1 (1.1)	1 (1.1)	0	50.56*	5
Measure and Evaluate during instruction	7 (7.4)	35 (36.8)	<u>50</u> <u>(52.6)</u>	2 (2.1)	1 (1.1)	0	57.58*	4
Analyze and give feedback to student	3 (3.2)	29 (30.5)	<u>54</u> <u>(56.8)</u>	8 (8.4)	1 (1.1)	0	104.48*	5
Measure and Evaluate on student participating in learning activity	6 (6.3)	42 (44.2)	<u>45</u> <u>(47.4)</u>	1 (1.1)	1 (1.1)	0	64.09*	5
Measure and Evaluate on student knowledge	6 (6.3)	<u>48</u> <u>(50.5)</u>	39 (41.1)	1 (1.1)	1 (1.1)	0	111.34*	5
Measure and Evaluate on student product	7 (7.4)	<u>46</u> <u>(48.4)</u>	38 (40.0)	4 (4.2)	0	0	30.21*	4
Measure and Evaluate by Portfolio	8 (8.4)	40 (42.1)	<u>39</u> <u>(41.1)</u>	5 (5.3)	2 (2.1)	1 (1.1)	49.87*	5

Remark: * significant 0.05 and the underline number is the highest percent in each topic

In Table 4.5, teachers measured and evaluated student learning in the more level of some topics. There was 56.8% of the teachers measured and evaluated consistently with objectives in the more level at the .05 level of significance. Teachers about 50.5% could measured and evaluated student knowledge in the more level at the .05 level of significance. Teachers about 48.4% of the teachers measured and evaluated student products. Most teachers were in the moderate level of measuring and evaluating in many topics. There was 48.4% of the teachers measured and evaluated consistently with content, time, and students in the moderate level at the .05 level of significance. Focusing on measuring during the instruction, there was 52.6% of the teachers. Mostly of teachers (56.8%) analyzed and gave feedback to students in the moderate level at the .05 level of significance. There was 47.4% of the teachers measured and evaluated student participation in learning activities. There was 41.1% of the teachers measured and evaluated by portfolio.

1.8.3 Opinion on Professional Development Needs

This section illustrated the findings of teachers' professional development needs. Many pieces of literature on professional development were analyzed in order to find common needs of teachers. Some aspects of professional development needs were provided in this section. These aspects consist of five categories: 1) science content (item a); 2) curriculum (items c, d, and e); 3) teaching technique and activities (item b); 4) learning media (items f, and g); and 5) collaborative working (item h). Teachers showed their professional development needs in every category. Most of the teachers strongly agreed with these items:

a) I want to improve my science content knowledge (50.53%)

b) I want models of science activities for enhancing student learning (55.79%)

c) I want to design integrated science content between science strands (69.47%)

d) I want to write systematical lesson plans for each grade (56.84%)

e) I want suggestions from experts about writing lesson plans (55.79%)

f) I want models of learning media for enhancing student learning (67.37%)

g) I want to learn about new innovative learning media (70.53%)

h) I want to work collaboratively with colleagues in planning instruction (47.37%)

The results of teachers' need of professional development presented that most teachers needed to develop in science content (item a), curriculum (item c, d, e), teaching technique and activities (item b), learning media (item f, g), and collaborative working (item h).

Teachers also proposed some needs for developing their science instruction besides the list of items provided in the questionnaire. They needed professional development in the areas of assessment and evaluation, creating new learning media, using multimedia and technology, introducing and facilitating local resources. They needed facilitation for using science laboratories and computer laboratories. Moreover, they suggested the need for science teachers who graduate in science fields and a reduction of teachers' responsibility concerning document work.

1.8.4 The needs for Participating in Professional Development

The responders showed interest in participating in professional development which was designed to respond to their professional development needs. In order to participate, they needed to score in the most (40.43%) or more levels (41.49%). Some responders were not interested in participating. Some teachers responded to participate in the less level (10.38%) and the least level (1.06%). The reason of the lower responses came from the feeling that those teachers did not like teaching science. The teachers who responded in less and the least levels of need for participating in professional development also gave the reason that they would retire soon. Some of them thought that participating would not make any changes in their teaching.

Conclusion of Teachers' Needs in Professional Development from Questionnaire

Teachers who responded to the questionnaire mostly were female and had teaching experience between 3-10 years. Most of them graduated in non-science fields. Most of them had experience in professional development that included: teaching techniques; writing lesson plans; science projects; remote professional development; science curriculum; using learning media/animation media; integrating learning; and analytical thinking. According to the findings of the questionnaire, they thought that their teaching practices were relevant to educational reform in the more and moderate levels in every focus area: 1) science curriculum development; 2) lesson introduction; 3) activities in science lessons; 4) use of media and resources; and 5) assessment and evaluation. Teachers mostly needed professional development with science content; teaching techniques (good models of activities for enhancing student learning); curriculum (integration between science strands, writing lesson plans for each grade, expert models for writing lesson plans); and learning media (updated models for enhancing student learning). Teachers needed to participate in professional development design consistent with their professional needs and current practices.

2. Teachers' Professional Development Needs and Current Teaching from Interview

This section aims for a deeper understanding of teachers' current teaching situations and their needs for professional development. The researcher was seeking more details after teachers responded to the questionnaire. The interview focused on their experience about organizational science learning, confidence with scientific content, and problems, challenges, or needs for improving science teaching. This interview was conducted in July, 2006.

2.1 Case 1: Ms. Pim

2.1.1 Pim's Background

Pim had 32 years experience as a teacher. She had taught science for 7 years. She said that she didn't have much science content knowledge, because she graduated in an elementary teaching field and was an English teacher for 20 years. She had to teach science, because there were not enough science teachers at school. She had learned science together with students. She mostly learned science by reading and asking other science teachers in the school. Teaching science before the Thailand reform period (statement in 1999, but full implement for all schools in 2003) was more flexible for her. She was not worried as much about science content, because the science curriculum for elementary science before reforming was integrated with social sciences and health sciences. In the recent reform, she felt that the science content in the new science curriculum was more in depth than before. She had to prepare herself with both knowledge and interesting activities for her students.

2.1.2 Pim's Current Teaching

According to her interview, she understood in reform. Her teaching trended to be more focused on the teacher, because she was strict to support students' learning based on learning outcomes in the core curriculum. She wrote lesson plans concerning learning outcomes in the core curriculum. She created a learning environment with a large amount of learning material such as science equipment, local and household equipment, and learning resources. She used hand-on activities. She realized to use authentic assessment to check students' learning with many kinds of other assessments such as mind map, product, report, and presentation.

2.1.3 Pim's Problems in Teaching

She faced some trouble in her science teaching. She tried to teach according to the educational reform, but her disadvantage teaching was that she often conducted lessons by herself. Moreover she had low expectations of her students about their thinking ability. She explained her difficulty on teaching as follows:

> After an experiment, I asked students to present their group work. I found that my students can do the experiment, but they cannot conclude their experiment in their own words. Finally I have to conclude the experiment for them on the blackboard…I think the challenges of this semester are about good experiments for the topic of precipitation and how to help my students conclude their experiments in their own words. I think that they are not good at thinking, which is a big problem when they take essay examinations, because they cannot explain their idea just like they cannot conclude the experiments (Interview 1, July, 2006).

2.1.4 Pim's Professional Development Needs

Upon her interview, Pim expected to learn good teaching strategies to help her students think scientifically which can help them conclude hands-on experiments in their own words. Also, she realized that she needed to update her earth science content to be more in depth than before.

2.2 Case 2: Ms. Keaw

2.2.1 Keaw's Background

Keaw had taught science for 15 years. She was the head of the science standard department at Radbumrun School. She loved to teach science even though she didn't graduate in a science field. She graduated with a bachelor degree in school administration. She was studying to receive her master's degree major in curriculum and teaching. She wasn't confident about the science content, but she always learned more by reading. She thought that teaching technique is more important than the actual science content. She was concerned with things that she had learned such as psychology, students' differentiation, and teaching technique combined with science lessons. She also held the view that science learning must be started from questions by the students. She said that she was eager for more knowledge in science as well as the history of science such as the inventors, because it is a good starting point of the students' curiosity.

2.2.2 Keaw's Current Teaching

She had a student centered view of teaching. This focused on students asking questions, building students' curiosity, hands-on activities, and using a variety of materials and assessments. She wrote lesson plans every year. Her lessons were designed activities from a variety of text books, which she followed objectives from her first time teaching the lessons. If she found it did not suit her students, she adjusted it later. She conducted lessons in 3 steps, which were introduction, instruction, and conclusion. She focused using questions to support students' thinking. She sometimes asked students do science projects at the end of the first semester. She used open-ended tests and presentations in class as supplementary assessments for evaluation.

2.2.3 Keaw's Problems in Teaching

Keaw had the same problems concerning students' thinking ability. She found that her students had low achievement in analytical thinking from the latest National Assessment Test in 2005. Her students could not talk about their ideas, nor conclude the activities. She has tried to improve these students to express their ideas.

> My students last year, they had low achievement in analytical thinking. I want to improve this situation. I want to start making them practice in presenting their ideas. I don't care if they make mistakes. If they think fast and present their idea more quickly, they could get more chances to develop their critical thinking which is important for scientific questioning. (Keaw's interview, July, 2006)

Moreover, from Keaw's interview, it showed some challenge points of copying an instant lesson and following it without consideration of the students needs. That way students having to go through a lesson not suited to them the first time will be like tired-out rats (researcher opinion).

2.2.4 Keaw's Needs for Professional Development

From interviewing, Keaw needed good activities to represent scientific concepts to students. Moreover, she needed a collaborative plan between teachers of grades 4-6. She hopes this will improve the problem of low basic science knowledge in the students.

2.3 Case 3: Ms. Yanee

2.3.1 Yanee's Background

Yanee has been an elementary teacher for 15 years. She had never taught just one specific subject. She has taught many subjects in her classroom including, Thai, Math, Social science, Art, and Science. She graduated with a bachelor's degree in agricultural education. She continued her master's degree in the curriculum and teaching field. Because of teaching many subjects, her teaching was sometimes designed for integrating subjects. For example, she used a whole morning for studying Thai and Social science. She asked students to read a Thai poem and then read the history involving the poem such as the writer of the poem.

2.3.2 Yanee's Current Teaching

Yanee had never written science lesson plans, because she chose to write Math and Thai lesson plans. For science teaching, she followed the textbook. Sometimes she adjusted the activities in the textbook. She didn't focus so much on science experiments, because there was not a science laboratory or equipment at her school. Yanee had to use materials that were easily accessible and from the environment around the students. She also took students out to learning facilities such as the zoo, museums, and a nearby forest. She normally conducted science teaching in 3 steps which were introduction, instruction, and assessment. She divided assessment into two sections; formative assessment encompassed 60% and summative assessment comprised 30%. She used a variety of assessment techniques such as reports, mini-tests, and mind-mapping.

2.3.3 Yanee's Problems in Teaching

According to her interview, Yanee wanted to improve her teaching with a focus on student centered constructing. She wanted to focus her science lessons on hands-on activities and experiments. She thought that if students have the opportunity for observation, experimenting, data collection, and concluding their activity, they would be able to construct their own knowledge. However, she couldn't do a great deal of science activities because there were no science materials or laboratory rooms in the school.

2.3.4 Yanee's Needs for Professional Development

She needed better materials and space for science teaching and learning.

2.4 Case 4: Mr. Boon

2.4.1 Boon's Background

Boon was a teacher with thirty-one years experience. He graduated with a master's degree in educational administration. His major was in general science when he was studying at the faculty of science. He started to be elementary teacher after graduating with his bachelor's degree. He loved science and taught that it was important for students to have scientific characteristic that included being observant, curious, patient, and reasonable.

> Science is the nature around students which they have learned their whole life. If we teach them to notice and be hands-on with the nature around them carefully, it will help them develop their thinking about things around them in reasonable way. They could bring this habit to real life, therefore, they will believe in themselves, being optimistic, being creative, and being moral persons. (Boon's interview, July, 2006)

He taught in various subjects, but he wasn't familiar teaching Art and Music. He brought the nature of science in teaching other subjects. For example, he encouraged students to present and discuss pressing scientific issues during the teaching of Thai. He encouraged students to notice the structures of things before drawing. He was concerned with the differences of children; therefore, he focused on what students learned depending on their physical and psychological development.

2.4.2 Boon's Current Teaching

According to Boon's interview and journal, he had beliefs consistent with student centered approach to teaching which focused on constructing knowledge through hands-on activities which were relevant to the students' age and development. During his current teaching he had never written science lesson plans because there is no science lab or science equipment in school, but he chose to write Vocation lesson plans. However, he had the process of science teaching in his mind. First, he analyzed the science standard curriculum and made a sequence of expected outcomes in each area of the science content, and then created his own objectives for each area of the science content that he would teach. He focused on students' experience in exploration and observation rather than experimentation. He sometimes brought other activities such as teacher questioning, teacher story telling, and student role playing in to science class. He used hands on materials from things and the environment around the students. He sometimes took students out to learning resources such as zoos, museums, and nearby forests. He assessed students both individually and through group work. Mostly he used observations of students' behavior in the classroom.

2.4.3 Boon's Problems in Teaching

He had the same problems as Yanee in lacking a science laboratory and equipment for enhancing students' experience by conducting several experiments.

2.4.4 Boon's Needs for Professional Development

He wanted ways to help students think actively, question, and have discipline which he thought was important to develop as scientific characteristics in students. He also wanted ways to help students draw on what they had already learned and apply that knowledge to real life. Moreover, he needed good, cheap materials for science learning.

3. Findings across the Cases

The four cases from the two different schools presented their differing current teaching situations, problems in teaching, and needs for professional development according to each individual school context. The findings across the cases discovered that school policies and environments affect teachers' current teaching, problems in teaching and teacher needs.

3.1 School Policy Effects on Teachers' Planning for Science Instruction

The findings showed that the school which has a policy of specialist science teachers in place influences teachers to make better plans for science instruction. The first two cases, Pim and Keaw, were from school A. They were science teachers with responsibilities for teaching science subjects in all classrooms in grade five (Pim) and grade six (Keaw). They wrote lesson plans for each year, but the majority of the lesson plans followed the text book. The interview showed that they had different styles in the designing of activities to compliment their lesson plans. Pim was more serious in finding science activities and adjusting them before using them in the classroom. Keaw was more dependent on implementing preplanned activities first, and then adjust them during the class because she thought that problems in teaching happen during instruction in the classroom. Sometimes these problems could challenge her students to think about how to improve the activities. If the activity was a failure, she would adjust or change it later.

Yanee and Boon from school B didn't write lesson plans because the school asked them to write only lesson plans in the filed that they were interested in. Both of them had to teach many subjects, but they didn't write science lesson plans because they could not find nice activities for students' learning in science without a laboratory. Therefore they taught science by following the text book which they had.

3.2 Teachers' Views on Learning Were Not Consistent with Their Current Teaching

All four teachers realized the requirements of the educational reform on organizing student learning by focusing on student centered teaching, which aims for students to construct their own knowledge. Mostly teachers talked about concerns with students as being individuals, thereby having differing interests, physical development, and psychological development. Their interviews showed that they were focused on the main roles of the teacher in students' learning; for example, as a conductor of experiments, introducing the topics in observations, and as more concerned about students' hands-on without mind-on and interest. These lead all four teachers to face the same problems with students who had low ability in thinking skills and could not conclude activities in their own words.

3.3 Student Thinking Skill Was the Common Problem

The four teachers faced the same problem in dealing with the low ability of student thinking skills. Their students could do the experiments, make observations, and follow everything form the teachers' instruction, but they could not discuss and conclude the relationship of the data that they gathered from hands-on activities. Moreover, both schools lacked of good science equipment, especially in Thamma School.

3.4 Designing Effective Lessons Was Common for Professional Development Needs

According to their common problems concerning the low ability of student thinking skills and lack of good science equipment, all four teachers had common needs for professional development in designing effective lessons that would encourage students to construct and apply knowledge to real life. It was difficult to prepare a good science laboratory in these two schools; therefore, teachers needed to design good activities which would help students learn science with higher thinking processes through higher science process skills by using cheap and easy to find materials.

Conclusion of Findings from the Questionnaire and Interview

The findings from the questionnaire indicated that there were many coherent teaching areas which should be improved. These coherent areas are: (a) teaching techniques involving engaging students' interests or curiosity, choosing the appropriate activities for engaging and supporting students' thinking, (b) teaching techniques involving a variety of hands-on and mind-on activities for individual students are needed, such as inquiry, problem solving, experiment, and discussion, (c) using local resources and things around the students' environment should be a higher priority for improving the situation of lacking science laboratories.

There were some areas dominantly present in the questionnaire which were concerned with improvement. Those were (a) professional development dealing with curriculum, especially analyzing core curriculum for writing good lesson plans which support student centered learning, and (b) professional development dealing with effective evaluation, especially formative assessments which could assess consistently with content, time, and students, authentic assessments which could assess student participation, and a variety of other assessment tools which support the learning of individual students.

Focusing on teacher needs for professional development, the findings from the questionnaire and interview were consistent. Most of the Pathum Thani teachers' needs were focused with good models of activities for enhancing student learning, writing lesson plans for each grade, and updating media for enhancing student learning. Some areas though, such as science content, integration between science strands, and expert models for writing lesson plans, were less emphasized in teachers' interviews.

Constructing the Professional Development Model Focusing on a Reflective, Inquiry Model for Earth Science Instruction

1. Goals of the Professional Development Model

The data of Pathum Thani students' learning (Pathum Thani Educational Service Area Office 1, 2003; 2004) illustrated that students had low achievement in science content knowledge and skills. This results was consistent with the data of Pathum Thani teachers' current teaching from the questionnaire that they improved their teaching, but teaching status was not fully effectiveness to support students' construction of their own knowledge and skills according to the reform. Pathum Thani teachers expressed their professional development needs that they want to improve their teaching in every topics of curriculum development, activities in science teaching, inquiry teaching, and collaborative working.

The vision of science learning on student-centered focusing on students engage in inquiry and the data of student learning, teachers' current teaching and their professional development needs were set the targets for teaching and learning improvement. The goals of the reflective, inquiry-based professional development model were a) to improve teacher understanding of inquiry and teaching skills to enhance student inquiry learning in the classroom and b) to develop a structure of the sustain professional development model focusing on teachers' collaborative working.

2. Objectives of the Professional Development Model

After the goals and the guiding principles and teacher needs for professional development were determined, the researcher constructed an in-service teacher professional development model focusing on inquiry/reflection for earth science instruction under these objectives:

1. To develop teachers' understanding of the concepts of inquiry learning and teaching by engaging in, discussion of, and reflection of the 5E earth science instruction and narrative activities including case-based pedagogy, construction of classroom cases, and metaphors.

From this objective, teachers will be able to:

1.1 Identify the characteristic of a 5E inquiry learning cycle

1.2 Create a model of a 5E inquiry learning cycle

1.3 Discuss the characteristics of inquiry learning activities

1.4 Analyze the role of the teacher and student in the learning process of a 5E instructional unit

1.5 Reflect on learning practices in a 5E instructional model, case-base pedagogy, and metaphors for constructing effective inquiry teaching.

2. To enhance teachers' practice of inquiry teaching through sustaining contact after the workshop by using a modified lesson study.

From this objective, teachers will able to:

2.1 Create and use a 5E instructional model for teaching earth science

2.2 Integrate narrative knowledge such as knowledge of curriculum, knowledge of instruction and student, knowledge of self, knowledge of subject matter, and knowledge of milieu in the 5E instructional model

2.3 Utilize a variety of learning activities, media, and assessments, thereby enhancing students' inquiry in to earth science lessons

2.4 Evaluate and reflect on practices through lesson study processes

3. Professional Development Design

The professional development model focusing on inquiry and reflection for earth science instruction was firstly developed as an English version under the management of two supervisors. The learning activities and document materials in the reflective, inquiry-based professional development were developed in a handbook form which consists of the program outline, instructor information sheets, and teacher activity sheets and worksheets. This handbook was later translated into the Thai language. It was audited by one expert elementary science teacher and two scientists in the earth science field for the appropriateness of the Thai educational context.

The steps for designing the professional development model focusing on inquiry and reflection for earth science instruction was affected by the way that the researcher planned the professional development model. This planning involved the process of design that facilitated elementary science teachers' learning based on notions of reflective and inquiry-based practices.

3.1 Selecting Earth Science Contents

The earth science concepts were selected according to the essential earth science topics presented in IPST curriculum for upper elementary grades (grade 4-6). These topics consist of (a) local rocks and their transformation, (b) soil formation, (c) weather conditions, (d) phenomena of climates, and (e) the water cycle.

The concept maps of these topics were created to find out the concepts (figure 4.2 and 4.3).

The researcher distinguished six main concepts. These were clouds, wind, the water cycle, rocks, weathering, and soisl. After selecting these essential earth science concepts, the researcher, together with the U.S. science educator, designed 5E instructions covering theses earth science concepts.

3.2 Selecting Learning Activities in 5E

Four guiding principles were considered for this step, especially, the consideration of activities in supporting a learner-centered approach and inquiry. The 5E instructional model was selected as the model for enhancing teachers learning earth science. Each step of the 5E was designed by Table 4.6 as guidelines. Moreover, the teachers' needs for professional development and Pathum Thani teachers' needs were considered when designing the activities for enhancing student learning, the updating of media for enhancing student learning, and effective evaluation. Effective evaluation included formative assessment which could assess consistently with content, time, and students, authentic assessment which could assess student participation, and a variety of assessment tools which support a variety of individual students.

3.3 Selecting Dilemmas for Case-Based Learning Activities

Pathum Thani teachers' current teaching situation presented some areas of needed improvement about student misconceptions in science, promoting student's question asking abilities and discussion, assessing with authentic and varying tools, and problem solving based teaching. These issues were considered as dilemmas for case-based reflection activities in this study. The researcher constructed four written cases using the case construction protocol in appendix C as a guide. These cases were open cases which contained unresolved dilemmas. The dilemmas of each written case were as follows:

Case 1: “Too many questions, too little time” This case’s dilemma is about teachers’ using questions to encourage students to construct their own knowledge of the water cycle.

Case 2: “Between a rock and a hard place: Assessment dilemmas in inquiry science” The dilemmas of this case concerns the teachers’ use of authentic assessment in inquiry teaching. Moreover, students’ alternative conceptions about rocks are focused as the second dilemma of this case.

Case 3: “Which way does the wind blow?: Conceptions change but not always as expected” This case focuses on students’ conceptual understandings of land and sea breezes. In this case, when two teachers co-teach, they encounter difficulties with changing student’s conceptions.

Case 4: “Soil and Scientific Problem Solving: A Dirty Dilemma” The important dilemma in this case focuses on how teachers can help children develop problem solving skills.

The teachers reflected on these cases with provided questions. They were expected to present ideas which would be beneficial for them to construct new ideas for inquiry teaching. The reflection through case based learning happens with group discussion and self-reflection. After reading the case, the instructor asked the participants to discuss in order to see what they understood about the case. Then the instructor writes down their opinions as understandings from class discussion. Finally, each of the participants was asked to reflect on their own opinions by providing questions at the end of each case.

Table 4.6 5E's activities

5E's	What the Student Does	What the Instructor Does	Suggested Activity
Engage	- Asks questions - Shows interest in the topic	- Creates interest - Generates curiosity - Raises questions - Elicits responses that uncover what the students knows or thinks about the concept	- Free Write - Analyze a Graphic Organizer - KWL - Brainstorming
Explore	- Thinks freely but within the limits of the activity. - Tests predictions and hypotheses. - Forms new predictions and hypotheses. - Tries alternatives and discusses them with others. - Records observations - Suspends judgment.	- Encourages the students to work together without direct instruction form the teacher. - Observes and listens to the students as they interact. - Asks probing questions to redirect the students' investigations when necessary. - Provides time for students to puzzle through problems.	- Perform an Investigation - Read Authentic Resources to Collect Information - Solve a Problem - Construct a Model
Explain	- Explains possible solutions to others' explanations. - Questions others' explanations. - Listens to and tries to comprehend explanations the teacher offers. - Refers to previous activities. - Uses recorded observations in explanations.	- Encourages the students to explain concepts and definitions in their own words. - Asks for justification (evidence) and clarification from students. - Formally provides definitions, explanations, and new labels. - Uses students' previous experiences as basis for explaining concepts.	- Student Analysis and Explanation - Supporting Ideas with Evidence - Structured Questioning - Thinking Skill Activities: Compare, Classify, Error Analysis

Table 4.6 (Continued)

5E's	What the Student Does	What the Instructor Does	Suggested Activity
Extend	- Applies new labels, definitions, explanations, and skills in new, but similar situations. - Uses previous information to ask questions, propose solutions, make decisions, and design experiments.	- Expects the students to use formal labels, definitions, and explanations provided previously. - Encourages the students to apply or extend the concepts and skills in new situations. - Reminds the students of alternative explanations. - Refers the students to existing data and evidence.	- Problem Solving - Decision Making - Experimental Inquiry - Think Skill Activities: Compare, Classify, Apply
Evaluate	- Answers open-ended questions by using observations, evidence, and previously accepted explanations. - Demonstrates an understanding or knowledge of the concept or skill. - Evaluates his or her own progress and knowledge. - Asks related questions that would encourage future investigations.	- Assesses students' knowledge and/or skills. - Looks for evidence that the students have changed their thinking or behaviors. - Allows students to assess their own learning. - Asks open-ended questions.	- Any of the Above - Develop a Scoring Tool or Rubric - Test - Performance Assessment - Produce a Product - Journal Entry - Portfolio

* Adapted from Bybee *et al.* (2006) and Szesze (2001)

3.4 Designing a Metaphor Activity

The undertaking of teachers creating their own teaching metaphor is also a main reflective-based activity of this professional development model. The teaching metaphor helps teachers to realize their role in teaching which could show the readiness for inquiry teaching. In this study, the participants are not familiar in writing metaphors. Therefore, the instructor designed a role play activity as a part of metaphor construction. Participants are asked to role play on some provided metaphors. They have to express their ideas on the metaphor that they chose. In role playing, the players try to present the metaphors meaning and the audiences try to get an understanding from the play. Through role playing, the participants are more familiar in expressing their idea through a metaphor. After that, the instructor and participants discuss each role play. The instructor prepares some metaphors for role playing such as a teacher as a gardener, a teacher as a nurse, a teacher as a director, a teacher as an actor, a teacher as a spy, a teacher as a physical trainer, and a teacher as a captain. The examples of preparing teaching metaphors are in appendix B. Finally, all participants are asked to create their own teaching metaphor.

3.5 Designing Activities for Modified Lesson Study

In order to support and facilitate teacher sustained change and growth, this professional development model was designed with a follow up phase that extended their learning after the short workshop. The teachers have opportunities to try out new ideas of inquiry teaching in their authentic classrooms by designing their own lessons. This phase focused on collaborative working among teachers with facilitation from the researcher. The evaluation of their learning also happens in their authentic teaching. This study used a modified version of the steps of lesson study so that it would be appropriate for the Thai educational context. The modified lesson study was designed for supporting teachers' professional development needs in a curriculum area, especially, in improving lesson plan writing. They had the opportunity to work collaboratively in analyzing core curriculum, designing lesson plans, and evaluating lesson plans.

After participants have learned inquiry teaching from 5E earth science lessons during the three day workshop, they could apply this knowledge for teaching in their respective schools. The researcher gained a greater understanding from four case study teachers who volunteered to show how they translated the knowledge of inquiry teaching into their authentic classrooms. Pim, Keaw, Boon, and Yanee were the case study teachers who were followed by the researcher to see their practices played out in the school.

The Convenience of modified lesson study was the focus of these four case studies. In the context of this study, Pim and Keaw are from same school but in different grades. They therefore needed to develop lesson plans on different topics. They worked with the researcher as a lesson study team of the Radbumrung School. Oppositely, Boon and Yanee were from the same school and taught the same grade. They taught in grade four. They were interested in developing same lesson plans for their teaching. Therefore, the lesson study team of Thama School consisted of Boon, Yanee, and the researcher.

The modified lesson study of each lesson study team happened at different places and times. However, there was a planned schedule that was the same for each of the lesson study research team meetings which were conducted to facilitate teachers work. The meetings consisted of a) introducing the lesson study meeting, b) planning the lesson study meetings, c) designing the lesson study meetings, d) meetings after teaching, and e) meetings after re-teaching. The modified lesson study took place from November, 2006 to February, 2007. Each research team worked together through these meetings in designing, teaching, revising, and re-teaching their lessons. At the end of the lesson study, all case study teachers were asked to write their own experiences in their classroom cases. Moreover, they were asked to create a second metaphor to represent their role in science teaching after completing professional development.

4. Validation of Professional Development Model

4.1 Member Checks

The process of checking validity by members happened when the researcher designed the first draft of the workshop handbook under the consideration of the U.S. supervisor and Thai supervisors who were members of the research team involved in designing the professional development model. Two supervisors were science educators and one supervisor was an earth scientist. The Thai and U.S. supervisors who were science educators were checking the validity of inquiry concepts, the relevance of activities in the 5E earth science lessons, cases for case-based pedagogy, and examples of metaphors. The effectiveness of the professional development model was considered under these guiding principles. They also checked the validity of tools for data collection in the professional development model that included interview protocol, journal protocol, and observation protocol. The earth scientist was the member who mainly checked the earth science content.

4.2 Auditing by Experts

The three experts of this study consisted of an expert elementary science teacher who was using 5E instruction during science class and succeeded as the teacher model for 5E inquiry teaching. Two earth scientists from the faculty of science were asked to be experts in presenting science content during the 5E earth science lessons. There were six main things from the handbook for professional development model that were audited:

1) The activities could represent science content correctly. There were some points about academic words or scientific words that should be more thoroughly considered.

2) It should have an overview that presents basic or general ideas about earth science for elementary teachers. The overview should be concerned with the holistic teaching of earth dynamics. It could be a 3 hour lecture of this information.

3) Some parts of the pedagogy in each step of 5E were adjusted or changed to be more relevant to the aim of having each step facilitating student learning.

4) At the end of each 5E activity, the instructor should give opportunities for the participant to reflect on the activity. They should write their role and the

instructor's role to represent how they understood inquiry. Moreover, they could also relay the advantages or disadvantages of the activity.

5) Case-based and metaphor activities were not changed, but they were checked for wording and the questions for reflection presented in the prepared stories.

6) The presentation for the first meeting, or "introduction to lesson study", was adjusted for content, wording, text, color and topic arrangement.

4.3 Selected Learning Contents

There were three days available for teachers to participate in the workshop. Therefore the researcher couldn't put all the content to be covered in a three day workshop. There were four main parts of the earth science content that were selected from the six designed earth science content areas. The soil and water content were not selected because teachers are more familiar with these concepts (Soparat *et al*., 2006). One added content area was "Dynamics of the Earth" which is expected for teachers to get a general overview of earth science. The earth scientist was invited as an expert lecturer to provide the general information of the dynamic of earth. This could be an excellent example of how an expert could take on the role of a local learning resource. The two parts of the inquiry content of case-based pedagogy in three day workshop were about questioning and assessment, which are consistent with teachers' need for improving their science instruction. The content, learning activities, and assessment of the professional development model were designed as follows:

4.3.1 Content

A. Earth Science Content

- Dynamics of the Earth
- Rocks
- Weathering and Erosion
- Clouds
- Wind

B. Inquiry Content

- 5E learning cycle
- Dilemma on inquiry teaching questioning on the water cycle
- Dilemma on assessment of inquiry teaching on the rocks topic

4.3.2 Activity in workshop

- Discussion
- Reflection
- Collaboration in groups

4.3.3 Activity in modified lesson study

- Collaboration within school teams for designing, teaching, revising, and re-teaching lesson plans.

- Self evaluation and reflection through writing journals

4.3.4 Assessment

The assessment was focused on the teachers' participation throughout professional development. The evidence of teachers' learning concepts and practice of inquiry consisted of teachers' artifacts, 5E lesson analysis worksheets, journals after the 5E lesson, lesson plans, journals from the modified lesson study, classroom cases, and metaphors.

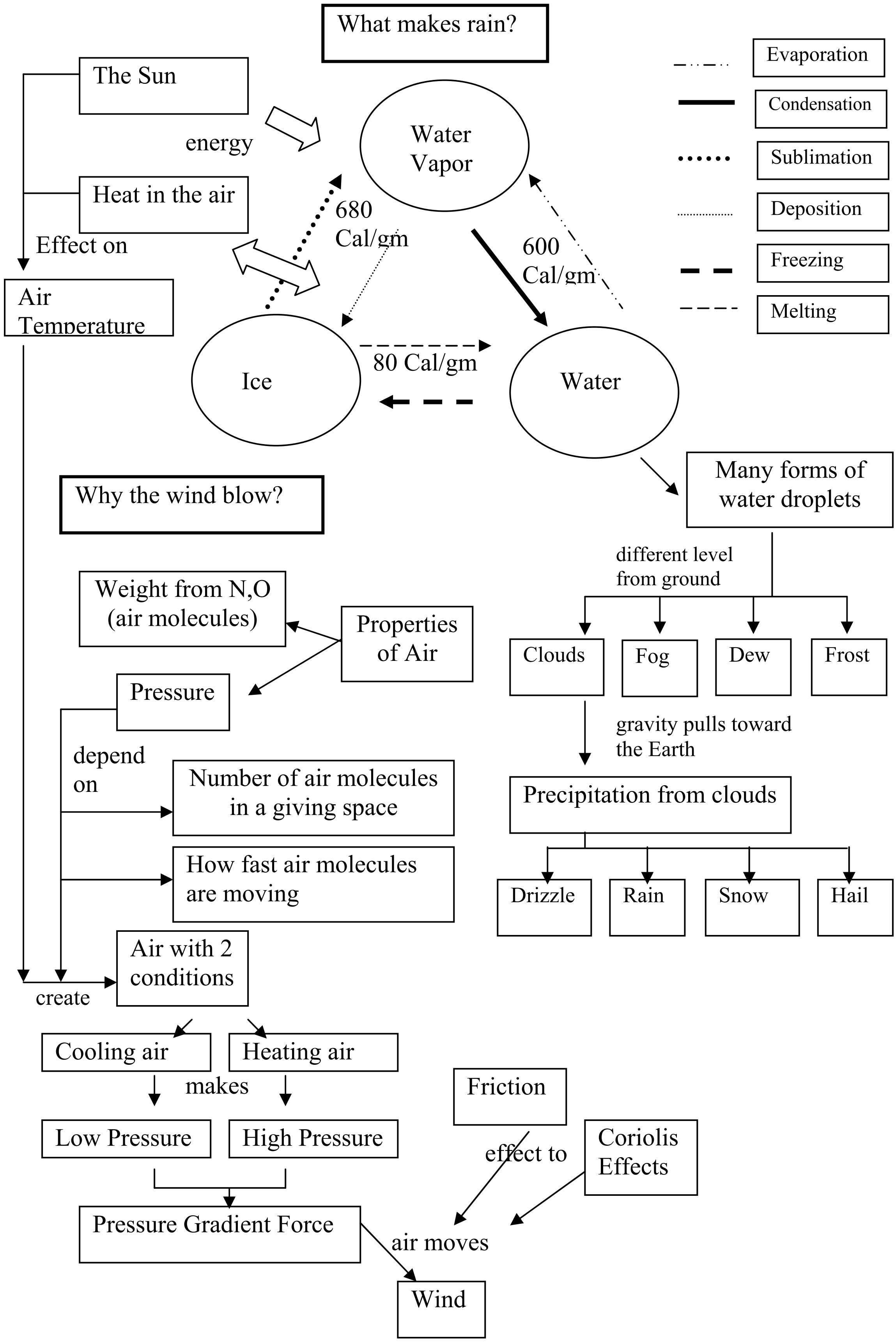

Figure 4.2 Weather Concept Map

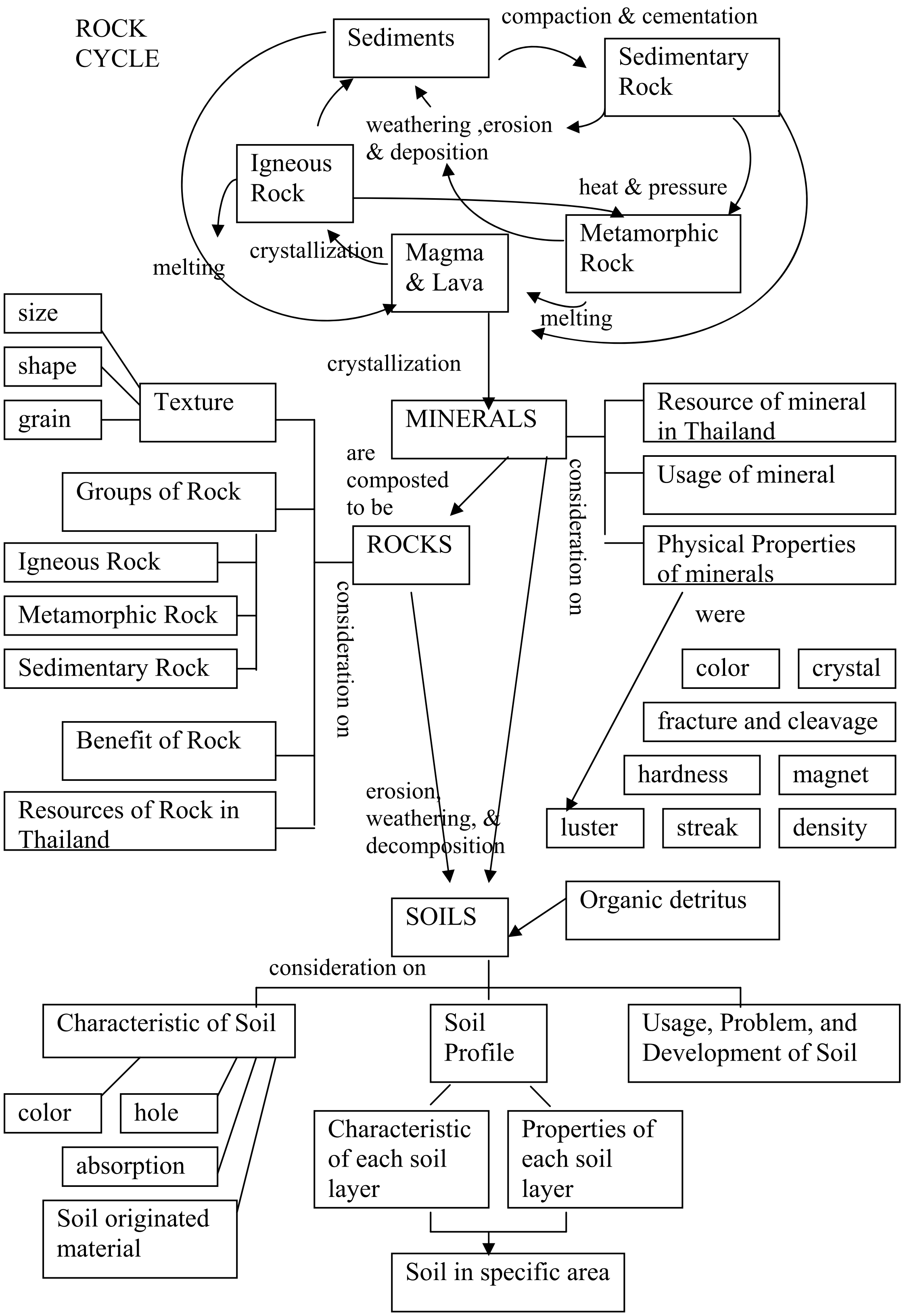

Figure 4.3 Rocks, Minerals, and Soils Concept Map

Outline and Scope of the Professional Development Model

The professional development model focusing on reflection and inquiry for earth science instruction aimed to develop teacher knowledge which emphasizes curriculum and pedagogy for inquiry in earth science teaching. The outline and scope of this professional development model is shown in Table 4.7 consisting of a three day workshop. Table 4.8 shows the activities in a modified lesson study as the follow up contact. The length of this professional development model was from October, 2006 to February, 2007.

The overview of the dynamics of the earth contained a lot of basic information for earth science. Therefore, the participants could get familiar with earth science. Moreover, some information was the basis for other contents. Some examples were the Earth's structure, the metamorphic cycle, the water cycle, and heat transfer. There were four expected science contents that teachers should learn through 5E instruction. At the end of the activity of the 5E earth science lesson, the participants were asked to analyze the instructor's role and participants' role. Teachers were expected to learn about both science content and pedagogy for inquiry. Case-based pedagogy activities were reflective sessions where teachers could think about the challenges and try to solve problems. Sometimes, they could compare provided situations to their classroom, which was beneficial in improving similar problems faced in their teaching. The first metaphor in the workshop was used to present teachers' hidden knowledge and beliefs about their teaching. It proved good evidence used to confirm teacher growth and change when compared to their second metaphor after they completed the whole professional development.

In the modified lesson study session, four case study teachers had the opportunity to develop their lesson plan by translating what they had learned about inquiry from the workshop. Teachers might learn something new during development and implementation of their lesson in the process of the modified lesson study because it focused teachers to be the learner from practice examples. Teachers did all the designing, teaching, and evaluating during their lesson plan and practice.

Table 4.7 The outline and scope of the three day workshop

Topics	Objectives	Activities
Learning Cycle	Teachers were expected to: a) identify the steps of the 5-E inquiry learning cycle, b) explain the aim of each step of the 5-E inquiry learning cycle, c) create a diagram showing their understanding of the process of the 5-E inquiry learning cycle, and d) analyze the role of the teacher and students in each process of the 5-E inquiry learning cycle.	E1: Brainstorming on prior teaching strategies E2: Perform an investigation, construct a model of 5E E3: Teacher explanation of their model, and discussion E4: Criticize a VDO of one teacher's teaching E5: Rubric for teachers' performance and products and journal writing
Overview of Dynamics of the Earth	Teachers were expected to: a) provide basic ideas about dynamics of the earth which will help participants to see the relationship between physical changes in the earth.	- Lecture by an earth scientist
Pedagogy case about inquiry teaching on the water cycle topic	Teachers were expected to: a) discuss and reflect on teaching practices, focusing on questioning and small group discussion in case-based pedagogy b) construct narrative knowledge of the role of the teacher and students in questioning and small group discussion to support inquiry learning for students	- Discuss and reflect on cases of inquiry teaching while questioning dilemma
Rocks	Teachers were expected to: a) observe and explain about characteristic of igneous rock, sedimentary rock, and metamorphic rock, and b) use rocks characteristics and property to create the system of rock classification.	E1: KWL about rocks E2: Perform an investigation on the characteristics of rocks, construct a model of rock classification E3: Teachers explanation of their investigation and model E4: Create a brochure about rocks E5: Rubric for teachers' performance and products and journal writing

Table 4.7 (Continued)

Topics	Objectives	Activities
Clouds	Teachers were expected to: a) experiment and explain about the formation of clouds, b) observe and explain about types of clouds, and c) search and create the parts of the cloud	E1: Read and analyze a situation in a cartoon E2: Perform an investigation through experiment, observation, research and classification of the types of clouds E3: Participants discuss their investigation E4: Thinking skills: matching and identifying unknown clouds E5: Rubric for teachers' performance and products and journal writing
Pedagogy case about inquiry teaching about the rocks topic	Teachers were expected to: a) discuss and reflect on teaching practices focusing on assessment in case-based pedagogy b) construct narrative knowledge of assessment to support inquiry learning for students	- Discuss and reflect on cases about inquiry teaching with an assessment dilemma
Weathering and Erosion	The teachers were expected to: a) identify the changes in rocks from both physical weathering and chemical weathering, b) explain the movement of rock and soil sediments, and c) find ways to protect the earth surface from erosion	E1: Brainstorming about the ways to break rocks E2: Perform an investigation through experiments E3: Participants discuss their investigations E4: Problem solving: protecting the Earth's surface from erosion E5: Rubric for teachers' performance and products and journal writing
Creating a teaching metaphor	Teachers were expected to: a) discuss and reflect on teachers' role hidden in a teaching metaphor b) create a teaching metaphor	- Discuss and reflect on given teaching metaphors - Create teachers' metaphors
Wind	The teachers were expected to: a) observe the effects of temperature to air pressure, b) observe air movement, c) observe the Coriolis effect to the direction of wind	E1: Demonstration on wind inventions and think about what these invention tell about the wind E2: Perform an investigation through experimentation E3: Participants discuss their investigations E4: Think skill: new situation E5: Rubric for teachers' performance and products and journal writing

Table 4.8 Outline and scope for the modified lesson study

Topic	Objectives	Activity
Team Meeting	- introducing the lesson study for the team - building agreement on the roles in team - selecting the lesson study topic	Meeting
Planning	- determining goals for the lesson study - selecting the lesson study topic	Meeting
Designing lesson plan	- selecting content, activity, media, and assessment for lessons - designing a 5E instructional lesson plan - adjusting teachers' lesson plans to be relevant to team goals	Meeting
Teaching	- implementing the lesson plan in authentic classrooms - investigating the effectiveness of lessons to student learning	Classroom observation by other members and the researcher
Discussing after teaching	- teacher explaining feelings of success in classroom - team suggesting about good points and weak points of the activity, environment, teacher, or students - team evaluating and recommending things to improve the lesson	Meeting after observation
Re-teaching	- implementing the revised lesson plan in an authentic classroom - investigating the effectiveness of the revised lesson to student learning	Classroom observation by other members and the researcher
Discussing after re-teaching	- mostly focusing on the teacher's feeling of implementing a revised lesson plan - evaluating and improving it for the next teaching	Meeting after observation

Summary

The professional development model of this study was designed for gaining an understanding about teaching inquiry with earth science content. The activities for enhancing teachers' understandings on concepts of inquiry teaching and learning were developed based on these guiding principles: (a) the learning process focusing on a learner-centered approach, which is effective in encouraging learners to gain knowledge and skills to their best potential; (b) teachers as reflective practitioners where teachers actively construct meaning from their prior experiences and practices; (c) teachers constructing knowledge of teaching through inquiry processes in which teachers seek ways to interpret their learning experiences to be used as a guide for inquiry teaching; (d) integrating elements of teacher change and growth consisting of learning new ideas in real situations, the inquiry process, committing practices with new ideas after a short training, emphasizing specific needs, evaluating new practices in their context, team-building, and facilitation along with new practices. According to the element of change and growth, the professional development model was designed with a short workshop and modified lesson study focusing on team building and facilitation to enhance the acceptance of new ideas in teachers' schools. Inquiry and reflection were given as support for teachers to construct their own knowledge of inquiry teaching. The activities during professional development were designed based on effective activities for inquiry teaching and learning, and also focused on the teachers' professional development needs for improvement of their science teaching.

CHAPTER V

FINDINGS OF TWO CASE STUDY TEACHERS FROM RADBUMRUNG SCHOOL

Introduction

This chapter presents the findings of two case study teachers from Radbumrung School. Pim and Keaw were participants of the professional development which consisted of two sections. The first section was a workshop designed to facilitate elementary science teachers' learning. The second section was a sustained contact in the modified lesson study. The findings of two cases in Radbumrung School are reported in two sections. The first section of the chapter focuses on the individual case of teacher's learning and practice in the context of professional development. The ideas addressed in this section consist of (a) teacher's initially understanding of inquiry, (b) teacher's understanding of inquiry during workshop, (c) teacher's practice, and (d) teacher's understanding of inquiry after lesson study. In the second section of the chapter, the findings from the cross-case analysis are presented. The pattern of teachers' learning, practice, and changes in practice and view of teaching were found and report.

Workshop Context

1. General Background of the Participants

The participants of this study were thirteen experience teachers. They came from two schools in Pathum Thani province. Eight teachers were from Radbumrung School and five teachers were from Thamma School. This study four experienced elementary teachers, Pim , Kaew, Boon, and Yanee participated in sustained contact activities. Pim and Kaew were female and teaching in Radbumrung school. Pim was teaching grade 5. Kaew was teaching grade 6. The other two case study teachers were from Thamma school. Boon was a male. Yanee was a female. They were grade 4 teachers. All four case study teachers held masters degrees in the education field.

Throughout the workshop, thirteen teachers participated in activities consisting of learning through 5E earth science instruction, discussing and reflecting about inquiry teaching dilemmas using case-based pedagogy, discussing and reflecting about teaching metaphors and creating of individual metaphors. The workshop was followed by a sustained contact component of professional learning which provided support for four case study teachers as they tried new ideas in their classroom.

2. The Case Study Teachers and Group Setting

Thirteen teachers participated in workshop entitle “Using the 5E’s Inquiry for Science Learning in Elementary.” These teachers were asked to sit in four groups on the first day. The instructor grouped them randomly by drawing lots. The groups on the second and the third day were reduced to three groups, because they changed their seats according to personal preference. Teachers were encouraged to sit in groups with mixed members from different schools.

3. The Role of Participants and Researcher in the Workshop

The researcher had the role as the “instructor” who conducted the activities of the workshop. The case study teachers; Pim, Keaw, Yanee, and Boon were participants of the workshop who provided fully data. The participants’ behavior during the activities were recorded on video tape. The researcher transcribed data on the video tape and analyzed to find the pattern of teachers’ understanding of inquiry during workshop.

The Sustained Contact Modified Lesson Study Context of the Radbumrung School Team

After the workshop, the researcher asked permission from Pim and Keaw to observe their classroom teaching before beginning the lesson study sessions. The objectives of this observation were to ascertain: (a) the level of inquiry in teachers' practice, and (b) the relationship between teachers' narrative knowledge and their practice in classroom. Insight from these observations were deemed beneficial for planning the 5E inquiry lessons. The findings from Radbumrung School team demonstrates high levels of many dimensions of inquiry teaching in accordance with the science teacher inquiry rubric (NRC, 2000; Beerer and Bodzin, 2004). After that two teachers worked collaboratively on the modified lesson study processes to design, implement, and evaluate the 5E lessons with the facilitator from the researcher.

This study used a modified version of lesson study so that it would be appropriate for the Thai educational context. In the context of the Radbumrung School team, teachers were teaching in different grades. Therefore, they needed to develop lesson plans on different topics. Pim was interested in the water cycle. Keaw was interested in the phases of moon. The steps of modified lesson study that were used in this study included: a) planning lesson plan, b) observing member teaching, c) revising lesson plan, and d) re-teaching with member observation. The schedule for lesson study meetings of this team is presented in Table 5.1

Table 5.1 The schedule for lesson study meetings in Radbumrung School

Date and Time	Steps of Modified Lesson Study	Activity
20 Dec 06 (2.05-3.10 pm)	Planning	Meeting for introduction of lesson study
30 Jan 07 (12.35-13.25 pm)	Planning	Meeting for designing lesson plan
15 Feb 07 (12.35-13.50 pm)	Planning	Meeting for adjusting lesson plan

Table 5.1 (Continued)

Date and Time	Steps of Modified Lesson Study	Activity
19 Feb 07 (9.30-11.30 am)	Teaching water cycle lesson by Pim (Grade 5/3)	Classroom observation by Keaw and researcher
19 Feb 07 (12.35-13.00 pm)	Discussion after teaching	Meeting for revising water cycle lesson
20 Feb 07 (9.30-11.30 am)	Re-teaching water cycle lesson by Pim (Grade 5/1)	Classroom observation by Keaw and researcher
20 Feb 07 (12.00-12.30 pm)	Discussion after re-teaching	for evaluate water cycle lesson
21 Feb 07 (12.30-14.30 pm)	Teaching phases of moon lesson by Keaw (Grade 6/2)	Classroom observation by Pim and researcher
21 Feb 07 (14.30-15.10 pm)	Discussion after teaching	Meeting for revising phases of moon lesson
23 Feb 07 (9.30-11.30 am)	Re-teaching phases of moon lesson by Keaw (Grade 6/3)	Classroom observation by Pim and researcher
23 Feb 07 (12.00-12.30 pm)	Discussion after re-teaching	Meeting for evaluate phases of moon lesson

1. The Roles of Members in Radbumrung School Team

As described in chapter 3, researcher had the role as the "participant observer" which was benefit for enabling the deeper understanding. Therefore, the role of the researcher in Radbumrung School team got involved in the setting of the team to responsibilities but did not participate fully in terms of members' values and goals. The members, Pim and Keaw, were expected to provide fully data with less interfere from the researcher. The role of the researcher in the team was the facilitator who guide the process for teacher planning, observations, and reflection sessions.

2. Setting Goals for the Radbumrung School Team

The team conducted two meetings to set goals for the lesson study. The objectives of these meetings were a) introducing lesson study to the team, b) building consensus on roles in team, and c) selecting lesson study topics. The agreement for this meeting was that both teachers would teach in their own classroom and others would come to observe and discuss each teacher's practice. Pim and Keaw determined goals for the lesson study and selected the science topics. They brainstormed goals which focused on a) the process of inquiry mainly student construction of questions through 5E's instruction, b) developing student knowledge according to science curriculum standards, c) developing science process skills. These goals were generated based on teachers' common problems in their classroom. They found that students rarely asked questions and could not describe concepts or phenomena in their own words, even those students who could finish activities by themselves, as described below.

Pim: "What should we support our students?"

Keaw: "I would like to enhance students to answer my questions and create their own questions in classroom"

Pim: "For me, I think about enhancing students science process skill and conclude science concept in their own words" (the second meeting)

Two teachers were thinking about ways to solve problems that were a) teacher using higher-order questions to support student thinking and asking question through all steps of 5E, b) teacher giving opportunity for students to try out and work collaboratively in small groups. They were in consensus regarding these goals as the following conversation indicate.

Researcher: "What teaching technique should we use for enhancing student understanding science process and asking questions?"

Keaw: "I think teaching techniques should be naturally to student. First, teacher should bring their idea out by asking good questions to activate them to think…."

Pim: "I am agree. Teacher should have good questions"

Keaw: "We should start from students' idea. Next, let them do follow their thought. Then ask them to tell what's happen from their work. If their work is not correct, teacher could support them such as how to do the correct way or what the correct answer"

Pim: "It's good. This way students can think about and learn science process from their idea."

Keaw: "Science learning should start from students' questions. However, this point is very challenge us. Our students are always keeping quiet, no questions, and no answers."

The Case Study of Teacher's Learning and Practicing through the Professional Development Model

The professional development model consisted of two sections of the workshop and the sustained contact on the modified lesson study. The workshop consisted of 5E earth science instructions, reflection on metaphor, reflection on case-based pedagogy. In order to see their changes and growth, the teaching metaphors which they wrote at the beginning and the end of professional development were compared in order to identified their changes in beliefs of teaching. Moreover, they were asked to write their own classroom case to reflect their knowledge of teaching at the end of professional development. This section reports the findings on teacher learning through these 5E earth science instructions and the sustained contact on the modified lesson study of each case study teacher in Radbumrung School. The findings of each case study teacher present in following

1. Case 1: Ms. Pim

1.1 Pim's Understanding of Inquiry Initially of Workshop: Teacher-Centered Teaching

In order to know about Pim's understanding of inquiry initially of the workshop, Pim was interviewed and asked to wrote the first metaphor. Evidence from the interview showed that Pim's understanding of inquiry was teacher-centered, emphasizing teacher's consideration for student learning experiences. The evidence from the first metaphor "teacher as a gardener" reflected Pim's intension for teaching was emphasized on students while her beliefs about the teacher's role emphasized on managing student learning which consistent with teacher-centered teaching approach.

1.1.1 Pim's Interview

Pim's understanding of curriculum development centers around notions of fixed content and fixed learning outcomes in the core curriculum. Her lesson plans were based on curriculum materials such as the IPST text books. She did not design activities using her ideas. She used instant lesson plans and choose the one which she believed to be most relevant to students. Pim mentioned that her instruction consists of a variety of materials, and assessment tools. As can be seen in her interview

> I use science equipment, local things, household equipment from students' houses, and learning resources such as museum, and garden in school. I assess my students with many tools such as mind-map, report, presentation, and experiment. (Pim's interview: July, 2006)

The questions in her instruction mostly came from the teacher. She found it problematic that students could not present ideas or conclusions after activities. She felt that the main factor for this problem was students' low level thinking skills**.** She wanted to teach consistent with student-centered approach and encourage students to construct their own knowledge.

1.1.2 Pim's Teaching Metaphor

Pim used a metaphor to describe herself as teacher as a gardener. Her reflection on the gardener metaphor showed that she perceived education must take time. Teacher must give a lot of attention educating students. A good learning environment is needed to grow students to become good citizens. Pim's described her metaphor as follows:

"Teacher as a Gardener"

> Gardeners expect on their trees which will grow up, be strong, resist to pest and germ and give them both quantitative and qualitative fruits. Gardeners have to pay attention to their trees from the beginning by planning and preparing so many thing for gardening such as land, seeds, study about nature of tree and how to take care. These roles of gardeners quite similar to teacher's role in teaching. Teachers have to expect on students learning. I always expect on student knowledge according to core curriculum and to be good citizen for society. Teachers have to prepare in many aspects such as: a) knowing the nature of students in order to help them for the best learning on their potential, b) knowing the science knowledge, pedagogy for science teaching, and teaching technique from reading, ask expert and peers, and c) knowing the local wisdom and integrate in science lesson(Pim's the first metaphor: 11 Nov., 2006)

Pim's gardener metaphor of science teacher, reflected of her narrative knowledge of science teaching in the following ways:

A. Teaching and Learning must Follow the Guidance (Knowledge of Curriculum)

Pim's metaphor showed that she planned for doing things based on guidance from on established curriculum. After planning, she prepared following her plans. The prepared things for enhancing students' learning mostly in the design of learning environment and herself. Then she carried out the actions on teaching (gardening). Finally, students should have learned in the ways that she expected. This reflects a very technical orientation to curriculum with little opportunity for student ownership participation. It is a linear, process-product model of learning which is inconsistent with student centered approach.

B. Teaching Involving Pedagogy, Students, and Content Knowledge (Knowledge of Instruction)

Some knowledge of instruction was reflected in Pim's metaphor. She specially focused on pedagogy, students, and science content as important elements for science teaching. She demonstrated concern for students' potential and the need to support their learning.

C. Teacher Managed Students' Learning (Knowledge of Instruction)

In Pim's view, the teacher is the key factors in student learning. The teacher guides what students do, filling their gaps in knowledge. Therefore, the teacher has to study hard to know more than students and be ready when students need help. This is consistent with a deficit view of knowledge, in which the teacher's role is to fill students up with the correct knowledge.

Conclusion of Pim's Initially Understanding of Inquiry

Pim's understanding of inquiry initially was consistent with somewhat teacher-centered level. From the evidence of initially interview and metaphor, Pim concern on student constructing their own knowledge, but her understanding reflected on evidence was contrast with her concern. Consideration on categories in science teacher inquiry rubric (NRC, 2000; Beerer and Bodzin, 2004), there were no evidence of students engaging by scientifically oriented questions, and students communicating and their conclusion. Pim had managed students ways of learning. She provides the procedures in textbook for the students to conduct the investigation. Then she explicitly states specific for conclusion.

1.2 Pim's Learning During the Workshop

Pim could develop science content knowledge through the process of inquiry centered around 5E earth science instruction. The evidence showed that she constructed correct concepts from hands-on and interaction with peers and the instructor. The process of analyzing the 5E earth science instructional segments encouraged Pim in learning how to teach inquiry using a 5E instructional model. The following are the patterns of Pim's learning during the workshop.

1.2.1 Pim Developed Science Content through 5E Earth Science Instructions

Pim's journal entries after 5E earth science instruction showed that she had learned more earth science content. This content was about the difference between rocks and minerals, classification of rocks, types of rocks, cloud identification, factors of weathering, and the cause of wind.

During Pim's participation in 5E earth science instructions, she joined the conversation of the class in the topics that she felt comfortable with, especially lesson of clouds and wind. In the cloud lesson, she showed that she had prior knowledge of the formation of cloud involving evaporation, condensation, and types of cloud conception. However, she didn't hold strong understanding of earth science concepts as shown in the conversation

Researcher: "Are there any idea about breaking rock in nature?"

Pim: "Some organisms could break rock for example, white ants, and fungi.

Researcher: "Any more exempla?"

Pim: "The column supporting house from water is also eroded by water"

Researcher: "How can we group these factors?"

Pim and Suchid: "Organism and Non-organism" (Pim's prior knowledge in engagement phase: 12 Nov., 2006)

While participating in 5E instruction on weathering, she improved her understanding of weathering in terms of specific factors of weathering organism, physical force, and chemicals. There was evidence from field notes showing that she had developed an understanding of physical forces break rocks. At the beginning of the weathering experiment, she had correct conception that air volume is reduced when temperature is reduced. But she had alternative conception that water has the same volume in every state of change.

Researcher: "What is your prediction for this experiment?"

Pim: "We thought about two predictions: 1) water balloon will be same shape because the water inside will be frozen as ice, 2) air balloon will be reduced size after the air is cooler. (Pim's prediction in explanation phase: 12 Nov., 2006)

After the experiment, she learned that frozen water in the balloon would extend its' volume and it could break a rock. Her understanding is illustrated in the following excerpt

Researcher: "Have you ever seen what happen in a glacier?"

Pim: "Yes. The ice could break rock. Normally, there is some water inside the rock or the under the ground. When the snow falls, water inside the rock will be frozen as ice. The ice is expand volume and it could break the rock." (Pim's discussion in explanation phase: 12 Nov., 2006)

1.2.2 Pim Developed Inquiry Content through 5E Earth Science Instructions

The evidence from analyzing lesson worksheet after participating in each 5E earth science instructional segment showed that Pim improved her ideas of given inquiry teaching, including more inquiry focus on students. She presented her understanding of each step of the 5E inquiry process as follows.

For the engagement step, Pim realized that students must be assessed more carefully on their prior knowledge, questions, and interests. Pim explained,

> Activities in engagement step used for probing students' prior knowledge and experience which is guidance for teachers' find the appropriate techniques in teaching (worksheet No. 4). Some activities were challenge students' thinking and questioning (worksheet No. 3). The materials in this step were interesting and general in students' life (worksheet No. 5).(Pim's analyzing lesson worksheets: Nov., 2006)

In relation to the exploration step, Pim learned that hands-on activities were important for students to see the real phenomena in science. Moreover, she emphasized the need to closely connect the engagement and exploration steps. Pim suggested that students should work collaboratively during this steps, with the teacher acting as a facilitator.

> In the authentic class, it is important for teacher to find out activities for connecting E1 and E2, because students could easily understand if they feel interesting in E1 (worksheet No. 3). When students work together, they could share ideas for finding answer. They could compare their predictions and the results from activities. They could find out the best answer of group (worksheet No. 4). Teacher should take role to look after students when they

are experimenting. Teacher should prepare material and safety in advance (worksheet No. 5). (Pim’s analyzing lesson worksheets: Nov., 2006)

In terms of the explanation step, Pim discussed her view that students should play a role as the explainer of their ideas after exploration. However, Pim felt that the discussion between students and teacher was very important for this step. Pim explained,

> Participants explained their idea after hands-on activities. However, the discussion of students in our classroom might miss some important points. It is the teacher’s role to explicit their ideas out (worksheet No. 3). (Pim’s analyzing lesson worksheets: Nov., 2006)

When describing the extension/elaboration step, Pim pointed that this step is beneficial for students, especially in terms of authentic practicing what they learned and applying that new knowledge. Pim wrote,

> Participants could authentic practice after conceptualize from E3 (worksheet No. 4). It is benefit for students to bring knowledge applying in some situation (worksheet No. 5). (Pim’s analyzing lesson worksheets: Nov., 2006)

For the evaluation step, Pim described many new evaluate tools. She noted that these tools are beneficial in providing evidence of students’ learning, easy to design, and relevant to authentic situations and formative assessment.

> The instructor used variety of evaluated tools, such as, observing, questioning, product, and quiz which are easy to design (worksheet No. 3). These tools are beneficial to evaluate participants and self-evaluate for participants (worksheet No. 4). Instructor used these tools to evaluate in whole lesson (worksheet No. 5). (Pim’s analyzing lesson worksheets: Nov., 2006)

1.2.3 Pim's Narrative Knowledge through Case-based Pedagogy

From the reaction on two written cases "Too many question, too little time" and "Between a rock and a hard place: Assessment dilemmas in inquiry science", Pim developed new ideas for using a variety of good techniques to foster student centered to solutions to the problems of questioning in inquiry lessons. She pointed out that formative assessment should be focused on assessing both students' product and process of learning. The following excerpts reflected Pim's knowledge of instruction as revealed in her case reactions.

A. Student Small Group Discussion Enhancing Conceptual Change (Knowledge of Instruction)

Pim agreed with using small group discussion as a way to bring students into the class. She mentioned that students should share ideas with friends in order to help each other construct. Pim explained, knowledge. In her view, students' sharing to ideas was beneficial for conceptual change. Pim explained,

> Small group discussion might help students to pay attention on exchanging ideas. It is important for students to share idea with friends to help adjust of conceptual change from misconception to correct conception (Pim's the first case reaction: Nov., 2006)

B. The Teacher as Facilitator in Questioning to Explicate Student Understand (Knowledge of Instruction)

Pim felt that it was important for teacher to ask questions to seek students' understanding and to give opinion for students to present idea and supporting them to discuss. However, she viewed that students need teacher's management for learning to take place. She explained,

> Teacher should well set the questions for challenging students in discussion. In case that there is little time, teacher should control the time. I might solve

> this problem by opening the discussion with the good ideas of some group (Pim's first case reaction: Nov., 2006)

C. Formative Assessment Focusing on Learning Product and Process (Knowledge of Instruction)

Pim proposed that teachers should use formative assessment to see the whole learning process of students, together with assessing their product after hands-on activities. She suggested that teacher could do formative assessment while students were working by using questions and asking them to present their ideas. Pim commented,

> Teacher should assess students' understanding in learning process and their product during student are working. Teacher could help students to present their understanding in learning process and their products by giving opportunity for students to discuss during they are working (Pim's the second case reaction: Nov, 2006)

D. The Importance of Students' Alternative Conceptions for Conceptual Change (Knowledge of Instruction)

Pim noted that students' alternative conceptions might be presented at the end of lesson. It is important for teachers to assess if this is the case. The lesson could then be extended. Pim explained how she would develop students develop correct conceptions and more profound understandings by designing appropriate activities for them after the end of lesson or next period. These activities might involve creating products or science projects. Pim emphasized,

> Teachers can help students' misconception develop to correct or more profound. They can find more activities to help students change misconception. They can use so many activities such as science project, produce products, making chart, and expositing board (Pim's the second case reaction, Nov., 2006)

Conclusion of Pim's Understanding of Inquiry During Workshop

According to the evidence from field notes, journal entries, and reflection around written cases containing dilemmas of inquiry teaching, Pim developed the understanding of inquiry in student-centered level. In the category of students engaged by scientifically oriented questions, Pim focused the main role in questioning, her purpose of questioning should not only for students' answer but also for students' creating questions. In the category of learners develop and evaluate explanation, Pim focused using of questions to lead students' explanation. Her questions were used for assessing students' conceptions, but not for changing students' conception. The questions were for finding appropriate activities to facilitate students' conceptual change. In the category of learner evaluate their explanation and learners communicate and justify their explanation, Pim perceived the benefit of students' discussion in conceptual change, reflecting a new perception that students could talk about their knowledge better than teacher. Moreover, Pim's reactions on written cases showed that she intended to use techniques of questioning, small group discussion, and formative assessment in her class focusing more on a facilitator role.

1.3 Pim's Practice: Changes to Somewhat Student-Centered Teaching

Pim's practice consisted of the practice on two lessons. In the "friction force" lesson as Pim's initially practice, there was many aspects a teacher-centered approach and less inquiry. Later, she could develop her practice to be more inquiry with many aspects of student-centered approach in the "water cycle" lesson.

1.3.1 Pim's Practice Initially Modified Lesson Study: A Teacher-Centered Teaching

Pim conducted friction force lesson using three steps of instruction; introduction, instruction, and summary. After finishing the workshop, Pim invited the researcher to see her classroom teaching on the topic of friction force. She designed a friction force lesson using three steps of teaching: introduction, instruction, and summary. The objectives of this lesson were (a) to investigate and explain how friction resists motion of objects, and (b) to give examples of friction from real life situations. Theses objectives were relevant to two of three expected outcomes of IPST curriculum on the topic of force. Pim's lesson did not include the use of the friction force in real life.

1.3.2 The Level of Inquiry of Pim's Practice before the Modified Lesson Study

Pim's classroom practice in the friction force topic when analyzed in relation to the science teacher inquiry rubric (NRC, 2000; Beerer and Bodzin, 2004) was a teacher-centered approach, as reflected in Table 5.2. She did not engage students in their own investigation. She provided specific questions for students to investigate, procedures for conducting the investigation, and directed learners' attention to correct conclusions.

In the introduction of the lesson, Pim determined the students' prior knowledge by asking questions, engaging students in a game, and connecting students' experience from game to real life by her explanation. The positive aspect of inquiry presented in this lesson was her use of questions concerning students' experience, but it was not sufficient to support students' inquiry learning in terms explicit prior knowledge. Most of the questions originated from the teacher. She also explained the concept of friction by herself, as illustrated below

Pim:	"Have you ever heard about friction force?"
Students:	"Yes"
Pim:	"Do you know that there is one force resisting the movement of things?"…
Pim:	"What do you feel, when you shove a big tank? Is it difficult to move? Why?"
Students:	"Because it is heavy"
Pim:	"It's because there is a force resist the movement of tank"
Pim:	"Have you ever slide on the slip floor? Is it difficult or easy to move?"

Students: "Easy"

Pim: "That's because the different surface effect on the movement of objects. Do you believe it?"

Table 5.2 Pim's classroom practice before lesson study

Steps	Classroom practice	Level of inquiry
Introduction	1. Teacher revised force concepts by questioning 2. Teacher told the definition of friction force 3. Teacher introduced game to challenge students to think about friction force 4. Teacher explained the result of game and lead students to the experiment	1
Instruction	1. Teacher asked question to lead students to problem 2. Students did experiment following direction 3. Teacher asked the questions to help students to see the variables and understand for the results 4. Teacher provided the conclusion of experiment	1
Summary	1. Teacher concluded each activity 2. Teacher tried to get students involving in conclusion with their own words, but they could do only answer teacher's questions 3. Students did the test in practice book	1

In the instruction of the lesson, Pim brought an experiment to the classroom. She asked an orienting question to lead students to investigate "Which surfaces make sandbag move fastest?" She provided the procedures for the investigation.

In the summary of the lesson, Pim concluded each activity and involved students in her discussion of conclusion in the following manner.

Pim: “If this sandbag moves fast, we would use less force. What does it show?

(Students were in quiet)

Pim: “Which friction presenting on the surface.. the more or less friction force?”

(Students were in quiet)

Pim: “If sand bag moves fast, is there more or less friction force resisting the bag?”

Students: “less friction force”

Pim: “Yes”

Pim: “Do you know friction force is depending on what?”

Students: “Surface”

Pim: “Therefore, you have learned that the surface of object effects to the friction force”

After summarizing the lesson, Pim asked students to do the test in their practice book which focused on students thinking about friction force in their real life.

1.3.3 Pim’s Practice of the “Friction Force” Lesson Was Not Consistent with Her Narrative Understanding of Inquiry

The evidence of Pim’s learning about inquiry during the workshop showed that she constructed new ideas about this approach. Pim’s practice in the “friction force” lesson happened after the workshop and presented low level some aspects of inquiry.

A. Lesson Plan Design Followed the Curriculum Document (Knowledge of Curriculum)

Pim’s friction lesson plan showed that her planning for student learning was relevant to what she believed about teaching and learning as reflected in her first metaphor. Her lesson plan was based on the guidance from the core curriculum. The learning objectives, teaching and learning activities in three steps mostly followed curriculum documents. The assessment was a test following the lesson which extended student learning by trying to connect their experience with answering question on the test.

B. Teacher Role as a "Teller" of Information (Knowledge of Instruction)

Pim's practice reflected the use of a variety of activities such as questions, games, and experiments, concerning students' prior experience and connected to their real life outside of school. However, some evidence showed that her lesson had less inquiry aspects. According to the science teacher inquiry rubric (NRC, 2000; Beerer and Bodzin, 2004), Pim demonstrated a teacher-centered approach in her practice. She provided learners with specificcally stated questions or hypotheses to be investigated. She provided specific directions on how data was to be analyzed. She directed learners' attention to specific pieces of analyzed evidence and guided them to a predetermined correct conclusion. There was no evidence of learners evaluating their conclusions or communicating and justifying their explanations. Pim demonstrated the teacher role as a teller of information, with most answers and conclusions coming from teacher. Her students could not give long explanations to her questions; therefore, she mostly used lower-order questions.

C. Teacher Held More Knowledge to Provide Students (Knowledge of Subject Matter)

Pim presented the correct concept on friction force in her conclusion (friction force is one kind of force which happens when two objects move against. It depends on kinds of surface, slipper surface has less friction helping object moves faster). However, she used mostly yes, no questions for student learning. She asked students to explain more from yes, no. If they could not explain, she would explain by herself.

1.4 Pim's Practice During the Modified Lesson Study: A Somewhat Student-Centered Teaching

In this section, the process of lesson study; lesson planning, teaching, revising lessons, and re-teaching are reported. The three main findings center on: Pim's translation of narrative knowledge into classroom practice; the students' learning; and the influence of lesson study on Pim's inquiry teaching.

1.4.1 Pim Translated Narrative Knowledge to Classroom Practice

Pim's knowledge from practice were compared to the narrative knowledge she constructed during the workshop. The findings of the influence of lesson study on Pim's inquiry teaching are described in each step of the modified lesson study of Radbumrng School team practice.

A. Lesson Planning

After the team set goals for fostering the student learning through inquiry learning, Pim choose the water cycle concept as a focus for lesson study. The objectives of this lesson were (a) experiment, explain, and tell factors that effect the water cycle, (b) explain the disadvantage of interruptions to water cycle, and (c) explain the ways to conserve in the water cycle. The first objective was relevant to the expected outcomes of IPST curriculum on the water cycle topic. The other objectives she designed for developing students thinking and attitudes toward water conservation. In her lesson plan and discussion with the team, she demonstrated knowledge of the following:

1) Water Cycle Is a Big Concept of Climate Change (Knowledge of Subject Matter)

Participating in lesson study gave her an opportunity for more systemic thinking about idea flow and prior knowledge needed for the lesson. Through the process of lesson design and concept flow that she got from participating in workshop, Pim could think more carefully about how to design concepts and the prior knowledge needed for students to understand the concept. Pim demonstrated an understanding of the conceptual sequence needed to understand a concept. She chose the water cycle, but realized that students needed prior concept and skills in order to understand the idea of water cycle. Pim noted,

> Water cycle is good to see over all of climate change. I take a look on the workshop handbook as you also presented water cycle as the conclusion of climate change. I agree, therefore, I plan to teach wind concept before water cycle. (Pim's discussion on the 1st meeting, December, 2007)

The water cycle lesson plan which Pim designed and brought to the team for feedback include an accurate on concept of water cycle. She explained the three state changes of water in the lesson to scaffold students' understanding of the water concept. In the water cycle lesson, she included technical words such as evaporation, and condensation and emphasized that her students should be able to explain these technical words. She had been taught these technical words in other lessons that she designed in 5E instruction for prior knowledge related to the water cycle lesson.

2) Lesson Plan Was Focusing on Science Process Skills and Student Thinking (Knowledge of Curriculum)

Pim had consideration for specific aspects of student understanding, and to demonstrated change in knowledge of curriculum: previously, she focused only on content and skills following curriculum. Pim demonstrated an understanding of the important of student-centered approaches and the need from teachers for thinking about students and try to set learning experiences that support their full potential and ability.

> I want to know whether the activities suit for objective and the steps of 5E. I tried to incorporate good questions, students' opportunity to think, raise

question and develop their science skill (Pim's discussion, the 2nd meeting, 15 Feb, 2006)

3) Small Group Discussion and Higher-Order Questions Were Used in Lesson Plan (Knowledge of Instruction)

The results from the analysis of Pim's lesson plan indicated that she translated knowledge which she constructed during workshop into practice. In the engagement step, she thought about higher-order questions which could provoke curiosity and questions. She had creative ideas on designing questions in a series of situations designed to help students practice their thinking. She used small group work and discussion in every step. She designed a variety of assessments during every steps of 5E inquiry instruction.

B. Teaching

Pim's teaching was somewhat inquiry oriented as it contained some aspects of inquiry, but not all aspects of inquiry. The analysis was based on the science teacher inquiry rubric (NRC, 2000; and Beerer and Bodzin, 2004) which was used as rubric to assess the level of inquiry for Pim's teaching. The results are presented in Table 5.3. As illustrated in Table 5.3, Pim prepared a series of question which helped learners to formulate a hypothesis about the water cycle. Next, students experimented to test their hypothesis of water changing states. She provided procedures and protocols for the students to conduct the investigation, which was teacher-centered. Then, she prompted students to analyze evidence and formulate their own explanations. Finally, students evaluated their explanations when they were prompted to examine their original explanation.

Table 5.3 Brief of activities with level of inquiry of Pim's teaching in grade 5/3

5E's	Classroom practice	Level of inquiry
Engagement	1. Teacher engaged students in water cycle topic by cartoon storied pictures which orienting questions to explicit students prior knowledge and curiosity 2. Students thought, analyzed and discussed about cartoon storied pictures and presented group idea to classroom. 3. Students were challenged to prove situation of water cycle: (a) what happens in the sky before raining? (b) where does water in the pond from? (c) How are clouds formed? (d) Where does rain come form? (e) Where does water in a pond go?	3
Exploration	1. Students read procedures of water cycle experiment. Teacher revised the procedures again. Students set water cycle experiment. 2. Students completed worksheet which contained questions about factors, result, and conclusion. 3. 3. Teachers gave questions for students discussing together on the result.	1
Explanation	1. Students created group chart about water cycle model 2. Students conclude "water cycle model in jar" in their own words together with their chart. 3. Students drew and painted the picture of water cycle in the nature. 4. Students explained their picture	4
Extension	1. Students read and analyzed a poem about water concerning lack of water in the future	Time out/0
Evaluation	1. Students generated chart and picture of water cycle in the nature from their understanding 2. Student individual lab report 3. Student working in group 4. Student evaluate their explanation	4

C. Revising Lesson

After observing Pim's lesson, team members including Pim, Keaw, and the researcher had a meeting for reflecting on Pim's actions. Pim was the first person to talk about her teaching, the strong and weak points, and things that needed to be revealed. Then, the team gave other suggestions and opinions on the lesson. According to the team's opinion, the strength of Pim's lesson were (a) the variety activities supporting the variety of students and (b) experiment helping students construct better understandings of the water cycle concept.

D. Reflection on the Success of Pim's Lesson

Pim felt good about her teaching of the water cycle lesson. She reflected on her practice that the variety of activities in one lesson was effective and responded to needs of a variety of students.

> I think 5E lesson is very good technique. I feel pity that I couldn't let students do all activities that I prepared. The 5E instructional model is very good that it helps some students have profound conception in water cycle, because there were many steps which I could design to help my students understand in same concept repeatedly. Moreover, with variety of activities, some lower ability students had opportunity to answer questions or give opinion during my instruction. (Pim's discussion after teaching in 5/3, 19 Feb, 07)

Keaw also supported Pim's feeling that the lesson went well. Keaw noted especially the water cycle experiment "water cycle in jar" which showed students that sun light has enough heat for evaporation, something that students cannot notice in nature.

> The experiment was very nice. When I think about water cycle, I am thinking about boiling water. At first, I was not sure that this experiment would work, because we don't have much time. But it was very nice to show students that the heat from sun could makes water vaporizing. We often told students that

we could dry the wet cloths by sun, but students had never seen how the cloths dried. (Keaw's discussion after Pim's teaching in 5/3, 19 Feb, 07)

E. Reflection on What Could be Improved in Pim's Lesson

Keaw thought that Pim should keep every activity same. But she had some suggestions for improving the lesson. They exchanged opinions and worked together to improve the water cycle lesson as follows:

- Correct the worksheet on the area for drawing the chart of water cycle after experiment

- Provide some clue to help students create the chart of water cycle such as arrow and technical words, because it was too difficult for students to state their idea on empty paper

- Prepare students to realize about water sources, because they had limited imagination about water sources in their pictures of water cycle in nature

- Reduce time for experiment to have enough time for elaboration/extension step

F. Re-teaching

Pim's re-teaching was somewhat inquiry oriented and contained some aspects of inquiry and other aspects that were not inquiry. This re-teaching was almost same. There was only small revisions to the student work sheet and some activities. Even though Pim tried to reduce the time of the experiment, there was not enough time for the extension step. The discussion about water resources of the earth took time.

1.4.2 Students Learning through the 5E Water Cycle Lesson

Pim taught the “water cycle” lesson in two classrooms. Her teaching was designed to assist students in achieving the goals of the Radbumrung School team. The students demonstrated the ability to formulate their own hypothesis about water cycle concepts. They had an opportunity to use science process skills in observing, recording data, creating and communicating their explanations, and creating models of the water cycle. They had knowledge of water conservation. The evidence of students’ learning in the “water cycle” lesson are presented follows.

A. Students in Grade 5/3

1) Students’ Alternative Conceptions in Engagement

In the engagement step, all groups of students presented their ideas along with their questions. Three alternative conceptions emerged during their discussion. The first was that heat made vapors condense to be water droplets. The second was that vapors drift to the air and attach each other to be clouds. The last was that the sky ,before raining, was black because of the color of the form sky.

In the exploration step, students conducted experiments following a procedure. After the “water cycle in jar” experiment, Pim helped student to conceptualize the water cycle through questions like the following:

Pim:	“How do you feel when touching this jar now?” all students touched the jar
Students:	“Hot”
Pim:	“What’s hot together with the jar?”
Students:	“Water”
Pim:	“What does the temperature change when the jar become hotter?”
Students:	“The temperature is rising”

Pim:	"What's else do you notice in the jar?"
Students:	"Water droplets"
Pim:	"Where?"
Students:	"Inside jar… All around the jar"
Pim:	"I would like you tell me how the droplets happen by drawing a chart and present to the class… every group" (Pim's teaching in 5/3, 19 Feb, 07)

2) Students' Conceptual Change through Hands-on and Discuss Activity

Students in each group created a chart of the water cycle and a picture of the water cycle in the nature. Students explained their idea of the water cycle again, after investigating through experimentation. Most groups explanation showed that students held correct conceptions. The following is an example of students' explanation of the water cycle. Group 5 was a group which initially held an alternative conception that heat makes vapors condense. Later, they explained the concept correctly.

> Water in the jar got heat, it was vaporizing to be vapors. When vapors got cold, the condensation was happened. The vapors became droplets. Droplets were collecting and heavier. They failed as rain which in water form. (Group 5 explained their chart from experiment: Pim's teaching in 5/3, 19 Feb, 07)

> When the water from the sea touch sun light, it will be vaporized. When vapors get cold air in the sky, they will be condensed to be cloud. When the cloud is getting bigger and bigger, it becomes falling as rain. The rain becomes the sea. It happens repeatedly as cycle (Group 5 explained their picture of water cycle in nature: Pim's teaching in 5/3, 19 Feb, 07)

B. Students in Grade 5/1

The students in both classrooms demonstrated similar understandings of the concept. There were some differences due to the nature of students in the class. Students in grade 5/1 more actively presented their ideas and engaged in more active conversation in their learning with each other and the teacher.

1) Students' Alternative Conceptions in Engagement of Revising Lesson

There were similar alternative conceptions about how clouds and vapors attach to each other and get bigger to form clouds. Moreover, there were different alternative conceptions about how vapors become rain, and how the sun sucks the water forming clouds, as reflected in the following conversation

Student group 4: "Was my presentation wrong?"

Pim: "It is not right nor wrong… I want to know how the sun suck water"

(Student group 4 consulted each other and answered)

Students group 4: "Sun is hot. The hot makes water vaporized"

Pim: "You called 'suck' because of this reason… I think there is other better word to be used"

Student group 4: "Vaporize"

2) The Experiment Made It Easy for Students to Understand the Water Cycle

Pim brought the experiment set to the class. As she was explaining the procedure for setting up the experiment, one boy suddenly demonstrated an understanding.

Teera: “Oh! I see! The water will vaporize up to the cover and turn to be droplets. They will drip to the little glass at the bottom of jar”

Pim: “How did you know?”

Teera smiled

Pim asked other friends in classroom “Do you believe him?”

3) Students’ Extending an Understanding of the Water Cycle to Other Situations

Students in grade 5/1 had an accurate understanding of the condensation concept after investigating during the experiment. Even though this class did not read poem, they had an interesting conversation about the water after condensation

Pim: “What is the color of water?” Pim took the small glass off the jar and showed to all students

Students: “It’s clear!”

Pim: “How to get this water?”

Students: “Droplets drip into the glass”

Pim: “Compare in nature, what does dripping water represent?”

Students: “Rain”

Pim: “Do you think this clear water is clean or dirty?”

Teera: “It depends on pollution in the sky. If the sky contains carbon dioxide, the rain will be dirty. If the sky doesn’t have carbon dioxide, the rain will be clean and we can drink”

At the end of class student were still discussing the lesson, nothing and that if the water cycle is destroyed, living organisms will not have water to drink.

Conclusion of Pim's Inquiry Practice

Pim's practice on the "water cycle" lesson was developed to reflect more inquiry than the practice on "friction force" lesson. Her practice in this lesson through the support of modified lesson study, demonstrated narrative understanding of inquiry which supported an increased understanding of inquiry teaching. This knowledge included knowledge of subject matter, knowledge of curriculum, and knowledge of instruction. Some of these knowledge was relevant to her narrative understanding constructed during the case reflection. This practical knowledge was teacher as facilitator, the importance student discussion, and the need for formative assessment. This evidence supported the assumption that Pim could translate her knowledge to practice. Moreover, some knowledge in her practice was developed from previous knowledge. She developed knowledge of curriculum which moved away from reliance on the text book, focusing more on her students during the process of lesson study.

According to the goal of helping students to become active in thinking and science skills, Pim was satisfied with her lesson. The lesson was successful in engaging students to answer the teacher's questions. There was no evidence of raising key questions from students, but the evidence of their conversation with teacher and their explanations showed that students could improve their thinking skills through hands-on and mind-on investigation of the water cycle lesson. They had a role in constructing knowledge through their curiosity about phenomena, observation through experimentation, making sense from the relation of factors and data results, discussion correct conceptions and evaluate on the conceptions. Pim's role was more facilitator who supported students' thinking and science skills. The conversation in small groups supported students sharing of ideas. Pim's higher order questions helped students to think. The assessment brought together to every step of 5E instruction and helped Pim realize what students knew, did not know, or misunderstood.

1.5 Pim's Understanding of Inquiry after Lesson study: Student-Centered Approach

The following evidence showed that Pim learned to improve her inquiry teaching during the process of the modified lesson study. Pim developed knowledge of subject matter, knowledge of curriculum, knowledge of milieu, and knowledge of self.

1.5.1 Pim's Narrative Knowledge Constructing after Professional Development

Pim was asked to write a second metaphor and a classroom case reaction which reflected what she had learned during the professional development. Her second metaphor was "teacher as a director." Her classroom case experience was "pushing forward…why the water gone?" The following findings describe Pim learned and how she gradually changed to inquiry teaching by enhancing the student-centered approach.

A. Pim's the Second Metaphor

According the first metaphor Pim wrote during workshop, she saw the teacher as a gardener. The first metaphor indicated that Pim's way of teaching was teacher-centered. She concerned what she taught more than what students learned, because she was more focusing on following curriculum. She took control in science classroom, while students were playing role under her expectation. After participating modified lesson study, Pim was asked to write a second metaphor. This metaphor was compared to the first metaphor to track her change. She wrote the second metaphor that teacher as a director

"Teacher as a Director"

> I belief that teacher looks like director, because director has the role to direct the actor to present their best potential in acting. Sometimes, director

> has to suggest many acting techniques, activate actor to present emotion, demonstrate acting if actor couldn't understand. In some case, director has to strict or complain on actors if they didn't pay attention to their acting, or rehearsal. In other hands, if the actor prepare his/her self with good rehearsal for the best acting, the director should give praise. In science classroom, teacher acts as director. Teacher asks students to inquiry, hands-on the activity by themselves. However, they need teacher to direct, take care, and suggest. Some students need little attention from teachers. Some students need demonstration before doing. Both of director and teacher have the same goal in profession on the need of actor or students to show their best acting in their best potential. The potential of actor or students is no limited, because they could rehearsal or inquiry if the director or teacher give them a good chance and good attention. (Pim's second metaphor, March, 2007)

In terms of Pim's second metaphor, there was not much change in her beliefs, even though her teaching practice was changing to be more student-centered. She was providing protocol for students' experiment in the exploration step. However, there were some changes in the second metaphor which effected from her changing practice. She realized that students had different abilities and needed chances to study by themselves. Teachers have to support students in inquiry to achieve the best results.

B. Pim's Classroom Case

Pim brought her experience in planning and implementing of the water cycle lesson in writing a classroom case entitled "Pushing forward… why the water gone?" The story is as follows:

"Pushing Forward…Why the Water Gone?"

> I have been taught from 1978 with experience in elementary grades from 1-6. Until the year 1989, I had to teach English for grade 6. I was very nervous, because I never have any experience in teaching English. However, I

had colleague to help and give me many suggestions. Also, I participated in many English workshops. My English teaching was getting better. I taught that I would taught English forever.

One day in the year 2001, an expert English teacher moved to this school. I was asked to teach Life Experience subject which consisted of social, science, and health science. I had to adjust my role of teaching for science. However, it was not much nervous for me, because I had belief that I could learn the new thing with great intension and providing time to practice on it.

In the year 2003, it is the new educational reform period. I took responsibility to teach both of Science and English subjects. I thought that these two subjects are totally different for their nature, teaching technique, and evaluation. Even I have taught science for many years, I don't have much confident in science teaching. Especially on the experiment. I have to try experiment before teaching. However, there always many problems in the real science class.

This semester (2006), I participated in 5E inquiry workshop. I got new idea for science teaching. I tried it in "water cycle" lesson. In engagement step, I designed to bring situation for students' discussion. I expected my students to be wonder where the water in the situation gone. It would bring my students to inquiry the answer for their wonder. But I was so surprise that my students could make a nice discussion. They could tell me the correct concept of water cycle in the first step of inquiry lesson. However, some students had the misconception on water cycle. Then I could bring students to the next activity. From this experience, I had learned that my students were much more clever than I thought. They have knowledge before class, but it is just not same level of knowledge in each student. They were not blank.

On that day, some students were active and interesting on activity so much. It was a good thing for both teacher and students, because we could learn together very effectively. However, there were different ability students

> in the class. Some clever students might be bored for the activity that they have known already. Therefore, teacher should have many techniques to respond the need and potential of group of students. From the experience on "water cycle" classroom, I realized that I need to accumulate more teaching experience. I could open students' view for their learning. It is not necessary for me to follow only teacher text book. (Pim's classroom case, March, 2007)

According to Pim's classroom case, she had developed a better narrative understanding of some aspects of inquiry.

1) Students Were Expected to be Active Learner (Knowledge of Instruction)

Pim translated her knowledge of inquiry into practice. She designed her water cycle lesson with the expectation that students should wonder about water state changes. She wanted them to discuss their prior knowledge and formulate their own question or hypothesis of water state change or water cycle.

> This semester (2006), I participated in 5E inquiry workshop. I got new idea for science teaching. I tried "water cycle" lesson. In engagement step, I designed to bring situation for students' discussion. I expected my students to be wonder where the water in the situation gone. It would bring my students to inquiry the answer for their wonder. (Pim's classroom case, March, 2007)

2) Students Were Not Blank Slates (Knowledge of Instruction)

Pim also realized that students were not blank slates, because they showed some prior understanding of water cycle.

> I had learned that my students is much more clever than I thought. They have knowledge before class, but it is just not same level of knowledge in each student. They were not blank. (Pim's classroom case, March, 2007)

3) Variety of Students Needed Variety of Activities (Knowledge of Instruction)

Students in Pim's class had different abilities. Pim realized that high ability and low ability students needed different ways of learning. Pim felt that teachers should be concerned about the different abilities to choose the right techniques to respond to different needs since the textbook could not respond to students' needs.

> There were different ability students in the class. Some clever students might be bored for the activity that they have known already. Therefore, teacher should have many technique to respond to need and potential of group of students. From the experience on "water cycle" classroom, I realized that I need to accumulate more teaching experience. I could open students' view for their learning. It is not necessary for me to follow only teacher text book. (Pim's classroom case, March, 2007)

4) Teachers as Learners (Knowledge of Self)

Pim realized that it is necessary for teachers to learn many techniques in order to respond students' diverse ways of learning, and to enable them to reach their best potential.

C. Things that Pim Learned through Her Practice in Lesson Study

Pim had improved her inquiry during participating in lesson study. The evidence from journal entries of her practice and discussion showed that lesson study enhanced inquiry teaching. She had learned new teacher knowledge during lesson study that were knowledge of instruction and students, knowledge of curriculum, and knowledge of milieu.

1) Improving Student-Centered Instruction (Knowledge of Instruction)

Pim could design and implement 5E inquiry lessons for enhancing students' thinking skills and science technical skills which helped her students construct the correct water cycle concepts by themselves. Moreover, students showed that they were active engage in activities and presented curiosity about the experiment.

A weak point of the lesson was about the extent to which the inquiry lesson used a student-centered approach. Pim still believed that students were too young to conduct investigations by themselves. However she learned that students could be good thinkers if the teacher provided them good opportunities and learning environments to support them.

2) Improving the Conception of Water Cycle (Knowledge of Subject Matter)

Pim learned that water cycle is the big concept which contained some sub conception that she had never thought to put in the lesson plan. She learned from conversation from students.

> I think water cycle is much more bigger than experiment. Many students know water cycle from previous lesson of evaporation, condensation, and cloud. I have the new concern of water cycle content. My students spoke about pollution and important of water that I had never think to put in my lesson. Now I think about the experiment of distill water together with benefit of water in real life such as drinking water from sea, salt farm, and using of fresh water. (Pim's discussion after re-teaching, grade 5/1, 20 Feb, 07)

3) Improving Utilizing of Curriculum Books (Knowledge of Curriculum)

Pim learned to use many curriculum books for preparing good activities instead of following them. She had more concerning on what students should learn rather what she should teach. She extended her view in knowledge of curriculum to focus more on student-centered approach which supporting students' thinking and science skill.

> I read many upper elementary science texts, IPST curriculum, and searching many activities about inquiry and water cycle from internet. I hope this will help me to plan the 5E inquiry lesson relevant to each step of 5E, design worksheet, tasks, test and questions which help my students to be more thinker. (Pim's discussion, January, 2006)

4) Working Collaborative Help Improving the Inquiry Instruction (Knowledge of Milieu)

During participating in lesson study, Pim learned to improve her instruction with colleague. She had more understanding on inquiry instruction which focusing on student-center approach through the systematic process of lesson planning and implementing.

> Organizing learning by using 5E is very important to plan systematically. We started with studying science curriculum and identifying: content, learning outcome, objective of the lesson relevant to students, learning media or resource, activities, and assessment. Teachers have to bring these components into 5E and prepare the questions which help students to think in this lesson. (Pim's journal, March 2007)

She also mentioned the value of peer collaboration in improving her inquiry teaching.

> During planning the lesson with Keaw, I felt that I have to be activated in study to improve the lesson. I wanted my lesson to be good lesson supporting students' learning. The effectiveness of the lesson would be advantage for my students…I learned from colleagues who observed me. The comments after my teaching helped me to improve myself and my lesson for next teaching (Pim's journal, March 2007)

5) Utilizing Teacher Experience to Improve Inquiry Lesson (Knowledge of Self)

Pim realized that teachers' teaching experience is beneficial in designing and implementing lessons. The less experienced teachers could learn from more experience teachers. New ideas were exchanged which was a very beneficial process for improving lesson.

> I think teachers who want to conduct inquiry instruction need to have some teaching experience. It will be benefit on knowing of science activities and student behavior… Comparing to Keaw, I has a small experience in science teaching. Therefore her advise is very benefit to help me plan lesson and revised my lesson. (Pim's interview, Febuary, 2006)

Conclusion of Pim's Understanding of Inquiry after the Lesson Study

After participating in professional development, there were changes in her understanding of inquiry. Especially she change to role to be a facilitator for supporting students to be active learner. She improved her narrative understanding of inquiry in every aspects. She improved to focus on student learning and content-based curriculum. She improved a variety of activities to support a variety of the students. She improved herself as a learner who needed to learn many teaching techniques to support students learning. These narrative understanding reflected her changes in inquiry practice. In terms of each category of inquiry teaching, she could develop every categories of inquiry to be more student-centered teaching.

Her teaching was in the highest level of inquiry in the categories of learners engaging by scientifically questions, learners formulate explanation, and learners communicate and justify their explanation. However, Pim practice in category of learners develop and evaluate explanations that address scientifically oriented question was still teacher-centered approach.

1.6 Pim's Growth after Participating in the Professional Development Model

Pim's growth was interpreted from the data throughout the professional development. During the workshop, she constructed an understanding of the inquiry from the analysis of the 5E earth science instruction and her reflection through written cases. Her practice changed from teacher-centered to student-centered and inquiry approaches. The evidence from the modified lesson study showed that she translated narrative understanding of inquiry into practice. Her classroom case also suggested evidence of the change to more inquiry oriented teaching.

1.6.1 Pim was Constructing Narrative Understanding of Inquiry

Pim developed an understanding of inquiry from analysis of the 5E earth science instruction. The evidence from the analyzing worksheet showed that she realized many aspects of inquiry were relevant to the student-centered approach. Besides constructing an understanding of inquiry through experiencing in 5E inquiry model, the case-based pedagogy supported Pim to construct the narrative understanding of inquiry. The narrative knowledge reflected in two written cases centered on the ideas of teacher as facilitator, formative assessment for assessing students' process and product of learning, and evaluating and using of alternative concepts to help students' conceptual change.

1.6.2 Pim Changed Her Teaching from Teacher-Centered to Student-Centered by Translating Her Knowledge into Practice

According to the evidence of Pim's practice during the modified lesson study, Pim could translate her narrative knowledge into practice. She brought her new ideas of facilitator, formative assessment, and evaluating and using of alternative concepts to foster students' conceptual change in the water cycle lesson. Moreover, she designed and implemented more inquiry than her previous practice. The evidence of her translating new ideas of inquiry from workshop to practice was also presented in her classroom case

> This semester (2006), I participated in 5E inquiry workshop. I got new idea for science teaching. I tried in "water cycle" lesson. In engagement step, I designed to bring situation for students' discussion. (Pim's classroom case, March, 2007)

1.6.3 Pim Changed Her View of Teaching to Be More Student-centered

Pim's classroom case showed many example of change in knowledge of inquiry. She expressed the view that students should be active learners who formulate their own questions and present ideas to friends. She learned that students were not blank slates, therefore she should not expect that students do not know anything about a topic. Instead, it was better to start from what students knew. She learned that it was important for teachers to design a variety of activities for a variety of students. If teachers only follow the textbook, this does not enable supported students to learn to their full potential. The other important view expressed was about herself as a teacher and learners. She realized that teachers needed to learn at all times for responding to students.

1.6.4 Pim Tended to Continue Inquiry Teaching

Pim thought that the 5E instructional model was very effective for enhancing students' learning. However, she felt that this model took too much time from teaching. She planed to conduct her lesson to be inquiry, especially by having students construct their own questions, explanations, and connections to other situation.

> I will bring 5E instructional model for other lessons, but I am not sure to design every lesson with 5E instructional model. It took much time to complete all steps. However, the process of students' constructing question, explanation, and connecting their knowledge to daily life were very good to bring in all lessons (Pim's journal: March, 2007)

Conclusion of Pim's Growth

According to the evidence of improving of Pim's practice, she could translate narrative knowledge focusing inquiry into her practice. she realized many aspects of students which were important for inquiry: students could make a nice discussion; students were not blank slate before the lesson; and students had different abilities in the class. There was a big change in her self as teacher also. She realized that her experience was valuable for inquiry teaching. She could design her own lessons most appropriate for students learning to take place. In contrast, the second metaphor showed that there was not much change in her beliefs of teaching. It is interesting to note that Pim didn't report her change in the second metaphor as she did in her journals, discussions, and classroom case. In term of her concern for the difference in students' ability in her classroom. Pim noted that there were many low ability students in her class. After implementing inquiry teaching, all students showed an improvement in learning. The high ability students learned fast and actively in inquiry activities. However, she noticed that low ability students needed time to think and act. She had to give help, suggestions, or directions all time. Perhaps, this is the reason why she still held onto the belief in teacher as director.

2. Case 2: Ms. Keaw

2.1 Keaw's Initial Understanding of Inquiry: Somewhat Teacher-Centered Approach

Keaw's interview and metaphor reveled her initially understanding of inquiry in somewhat-teacher centered which contained some categories of inquiry teaching in lower and higher level of inquiry. The findings from the interview showed that Keaw was teacher-centered teaching with the role as a coach who concern on setting learning experience focused on content. The interview showed that Keaw had an understanding of constructing lesson plans which focused on the subject, but not much on students and society. In contrast, her metaphor "teacher as a six-side mirror" reflected her understanding of inquiry teaching in student-centered approach. She wanted to let students selected their own way of learning with her consideration on their learning outcomes.

2.1.1 Keaw's Interview

Keaw's interview reflected low level of inquiry in her science teaching. There were two patterns of Keaw's understanding of inquiry emerged from her interview. These patterns were teacher-centered approach

A. Teaching is Based on Content-Based Curriculum

Keaw started planning the learning experience for students by analyzing the core curriculum, dividing sub-topic of each science strand into a lesson, and determining the duration for teaching each lesson. She focused the activity for each lesson based on what was found in the general textbook. She used the activities from the textbook and followed the objectives and procedures exactly. She thought that objectives could be changed later if they did not fit with the students. She described this process as follows.

> I design learning activities from science instant lesson plan and follow its objective. I think these instant lesson plan were well designed from the experts. It could be reliable. I would change or adjust them later if I found that they were not suit for my students or my teaching style. (Keaw's interview: July, 2006)

B. Teacher as a Coach

Keaw preferred to ask questions to students rather than responding to their questions. She thought that questions were important because they provided students with as opportunities to think and present their ideas, which is basic to investigation. After the lesson, she used open-ended tests and presentations to assess students' learning. She described her teaching in following manner:.

> I conduct lesson in 3 steps, introduction, teaching, and summarizing. I put every step with activities and use questions before and after each activity. I sometimes ask student to present their ideas after activities. I prefer to use open-ended test instead of multiple choices test for final examination. In some year, I asked students to do science project at the end of semester. (Keaw's interview: July, 2006)

Keaw realized that Thai students were shy about speaking out and not familiar with posting questions. She hoped that inquiry teaching would help students be curious, critical thinkers, and would encourage them to construct knowledge.

2.1.2 Keaw's Teaching Metaphor

Keaw described herself as a "six side mirror" in her teaching metaphor. It reflected a student-centered learning which illustrated that the student is a person who conducts his/her own life including the way of learning. He/she can learn in the way that they choose, but should know the suggestions of the teacher. She described her personal metaphor as follows:

"Teacher as a Six-Side Mirror"

Mirror is a surface which can reflect the image of the object in front of it. Everybody has to use mirror to see the readiness or beauty before going out home. Somebody looks at mirror several times for their confidence before going out.

In childhood, parents are the first teacher for children. Children learn many things from parents. However, I think parents could be only one-side mirror who look at their children with only good parts. For me, I think that teacher could see children in many parts.

Teacher as a six-side mirror could reflect children in many views such as the front, back, right, left, top, and bottom sides. Everybody has both of good and bad parts. When I see some bad parts, I would like to improve my students. I want them to live in the society very happily. However, it depends on the students whether they want to improve themselves. (Keaw's the first metaphor: 11 Nov., 2006)

According to Keaw's six-side mirror metaphor, Keaw's science teaching viewed in the following ways.

A. Teacher Emphasized the Importance of Students Considering Themselves (Knowledge of Self)

Keaw realized that parents are the first person to educate students. When students go to school, teachers then have the responsibility to educate them. Keaw was concerned about the students to conduct their own lives. According to Keaw, it is the parents' and teacher's duty to suggest, but not to direct them. In her sense, parents might have some bias so as to see only good things of the children. Therefore teachers have to help parents reflect all aspects of their children and give suggestions to them.

B. Learning Happens by Students (Knowledge of Instruction and Student)

According to her metaphor, Keaw felt that students develop their own ways of thinking. They might think correctly or incorrectly. Teachers teach them by reflecting about their thinking, not by directing their thinking. Therefore, the teachers' role is to question the students' ideas. Students should have open minds, discuss their ideas, and be ready to adjust in the appropriate way.

Conclusion of Keaw's Initially Understanding of Inquiry

Keaw's understanding of teaching was consistent with a somewhat teacher-centered approach. Keaw chose to emphasizing content in the textbook curriculum, with little concerning for students. She chose learning experiences from textbooks, not on the needs of students. She assessed students in ways designed to the content, consider their understanding on activity. Base on the inquiry teaching category of engaging students in scientifically oriented questions, Keaw's knowledge of instruction was focused on questioning rather than students questioning. Her questions were used in guiding students teach to investigate and formulate conclusions. In the category of student developing and evaluating their explanation from evidence, Keaw was realized on the point that students could not construct their own knowledge by themselves and had low thinking ability, therefore she used her questions to guide them thinking. Keaw's understanding of inquiry from six-side mirror metaphor reflects her belief that students could conduct their own learning. The important role of teacher is to reflect on students' learning. Keaw beliefs are very consistent with the student-centered approach in which students have different interests, abilities, and styles of learning. These teachers need to prepare learning experiences to support students highest potential, with a variety of activities and assessments. Keaw's perception for organizing learning experiences for students was consistent with student centered-approach, but she conducted the instruction with teacher consideration. Therefore her way of teaching was reflected in somewhat teacher-centered inquiry.

2.2 Keaw's Learning during the Workshop

According to data from field notes, worksheets, and journal entries, Keaw learned earth science content and aspects of inquiry teaching and learning. The details of her learning are described below.

2.2.1 Keaw Developed Science Content through 5E Earth Science Instructions

Keaw learned many earth science concepts by participating in 5E earth science instruction. According to her journal entries, she mentioned that she had a better understanding the difference between rocks and minerals, the criteria for distinguishing types of rocks, types of cloud, the difference between weathering and erosion, the characteristics of weathering and erosion, wind formation, and the Coriolis force effect on oblique wind.

A. Keaw Developed the Earth Science Contents through Curiosity, Question, and Investigation

Keaw demonstrated her learning by creating questions for classroom investigation. While participating in 5E instruction on the cloud and wind lesson, she learned new earth science concepts. She started her learning with questions. Then she tried to investigate and construct her own explanation. An example of Keaw's developed her understanding during the activity "cloud in bottle." Her understanding is illustrated in the following excerpt.

Keaw: "If I want lots of cloud, should I put more matches?"
Researcher: "You can try"

After the experiment, the researcher and participants discussed the factors in cloud formation which were represented in the experiment. The researcher asked Keaw what she found in her experiment.

Researcher: "What did you find when you put more matches?"

Keaw: "I think it had more cloud"

Others: "really?"

Keaw: "Yes!"

Keaw: "The cloud in the bottle looked just the thin layer. When we squeezed the bottle, the pressure and temperature will be increase. The smoke from matches will create the core for cloud. Therefore when I put more matches, there would have more cores for cloud formation" (Keaw's discussion in exploration and explanation phase: 12 Nov., 2006)

Moreover, Keaw was active in predicting the outcomes of investigations. The predictions from participants were very meaningful for their thinking process, which is an integral aspect of hands-on activity. In addition, teachers' predictions enhanced the learning environment for all participants, as they were alert to think and share ideas as active learners.

Keaw realized that curiosity was an important factor in leading students to have questions. Teachers should take into account students' curiosity, as a way to lead them to think about what they want to know and how to investigate. She noted in her journal that

> It is interesting to reinforce students' curiosity in engagement. I think it is good to let students have experience during exploration and make their own analysis for present their idea in explanation. I could adjust it to my lesson plan. (Keaw's journal: 12 Nov., 2006)

2.2.2 Keaw Developed Understanding of Inquiry through 5E Earth Science Instruction

In the engagement step, Keaw mentioned that this step of 5E inquiry would be beneficial for students by enabling them to present their understanding or prior knowledge. She emphasized the importance of students having opportunities to think and express ideas. Keaw felt that the teacher played a significant role in asking orienting questions for stimulating students' thinking. Keaw explained,

> The instructor played role in preparing interesting situation and orient questions to stimulate the participants' ideas (worksheet No. 3) The good point was that students had opportunity to participate (worksheet No. 3)and be engaged to think about what they would learn (worksheet No. 4). (Keaw's analyzing lesson worksheets: Nov., 2006)

In the exploration step, Keaw thought that activities should focus on hands-on experience. She felt that the teacher should facilitate students' learning experience by preparing the equipment and making suggestions about the experiment.

In terms of the explanation step, Keaw thought that students' discussion was important and a necessary step for them to arrive at conclusions. Keaw felt that teacher should participate in the discussion as facilitator by giving clues or asking some important questions to help students' construct knowledge.

In the elaboration/extension step, Keaw realized that students could extend their knowledge through additional investigation. Keaw emphasized that teachers could engage students again in this step by using orienting questions. Students participate in activities to search for answers to extended questions.

In term of the evaluation, Keaw noted two particular features of evaluation in the 5E instructional model. The first feature was the examination of understanding by teacher and by students. The second feature related to providing students the opportunities to revise their understanding. Keaw noted the importance of having the variety of assessment tools. She noticed that important tools for evaluating were mostly teacher's observations and questions.

2.2.3 Keaw's Narrative Knowledge through Case-Based Pedagogy

Keaw's reflection on two written cases showed that she developed an understanding of aspects of inquiry teaching and how she could support student-centered learning.

A. Student Small Group Discussion: the Opportunity for All Students to Present Ideas

Keaw believed that individual expression of ideas was important for students' learning. According to the previous interview, she was troubled by the fact that students could not explain their ideas even when she tried to support them. This problem was also the dilemma of one of the cases "Too many question, too little time." After reading and discussion, she learned that small group discussion might enhance students' abilities to express ideas better than large group formats.

> Using small group discussion would give opportunity for all students in the class thinking on the same topics and presenting ideas. This way students will be concentrate on other ideas. Moreover it is the opportunity for all students to pose questions to friends. Therefore students should learn to be good listener and good speaker. (Keaw's the first case reaction: Nov., 2006)

B. The Teacher as a Moderator to Motivate Student Discussion

After reading the first written case, Keaw noted that the problem in the first case related to students ability to engage in discussion. According to Keaw, the problem happened because the teacher was not clear about, the students conversation. She emphasized that teacher should have encouraged student discusses on the same topic. She described the role of teachers in enhancing student discussion as follows:

Teacher should well choose the issues in class discussion to find out the ideas of all students. Teacher should have role in asking questions, motivating students to answer, and gathering students' ideas from their discussion. The students should have role in answering question and brain storming. (Keaw's the first case reaction: Nov., 2006)

C. Learning by Copy: the Result of Students Have No Ideas or Misunderstandings Their Teachers

From the group discussion on the second written case "Between a rock and a hard place: Assessment dilemmas in inquiry science", Keaw reflected on the issue in the case which a student was copying others' work. Keaw posted her idea for the group discussion as follows:

Keaw: "I think that student copy work is a kind of learning experience. At least, he noticed how to learn. In the other hand, it is not good if that student always copy. All teacher wants our students to think by themselves. However, this case realize that maybe student doesn't have enough basic knowledge, then he had to copy."

Boon: "Actually, it is good. In this case, the copy group admired the template group for the work process. The copy group became convince and wanted to be success. Then they learned the process to help them success. About the point how to know the copy group has understanding, teacher has to assess them more. Teacher can talked with the copy group or ask them to present to the class."

Suchid: "The more important thing about copy issues, I think we should focus on "why do our students copy?". Should we ask ourselves? Maybe those student don't understand on what they do. They know that they have to finish it even they don't know what they have to do about rocks. I think teacher's objective is very important. It is better for teacher to make sure that students understand the objective. I think if they understand on objective the behavior of copy will be reduced."

> Keaw: "I agree. We cannot let our students copy all times." (Keaw's the second case discussion: Nov., 2006)

According to the discussion on the second written case, Keaw stated her ideas that copying is not good thing in terms of enhancing students' abilities to construct knowledge. However, she pointed out that copying was a kind of learning for some students who did not have enough basic understandings. Later, she was realized the point that teachers should start to think about copy as perhaps the result of the teachers' weak communication in terms of enhancing students understanding as objectives of their learning.

D. Formative Assessment: Evaluating along the Way

After reading and discussing the second written case, Keaw reflected on her views of assessment in ways consistent with formative assessment methods. Moreover, she noted that she preferred to give feedback after assessment to students immediately. This approach is consistent with assessment which focuses on assess for development of the learner. According to Keaw, assessment should happen along the way of students' learning. However, she did not mention any specific assessment tools. She noted,

> Teachers can assess students' understanding in many chances: (a) during students are working, (b) after students finish their work, (c) when students have questions and raise their questions to class. Teacher uses questions to motivate students to present their thinking and learning process which teacher also assesses, encourages, and strengthens students' answers." (Keaw's the second case reaction: Nov., 2006)

Keaw also suggested that formative assessment during the learning process was beneficial in helping teachers notice students' alternative conceptions immediately. Therefore, according to Keaw, teachers can facilitate students conceptual change by using techniques such as simulations, drawing, role play, and story writing which enhance students' understanding.

Conclusion of Keaw's Understanding of Inquiry during the Workshop

Keaw developed science content knowledge while participating 5E earth science instruction. She constructed an understanding of science concepts through the process of inquiry consisting of questioning, planning, investigating, concluding, discussing, and constructing correct conceptions. She also constructed knowledge of inquiry teaching and learning through the process of analyzing the 5E earth science instruction and reflecting on the written cases. She explained the aspects of inquiry and the teachers' and students' role in each step of 5E inquiry model, consistent with a student-centered approach. Especially, the category of inquiry teaching focusing on students engaging in scientifically oriented questions, Keaw wanted to improve students to be the questioner. In the category of learners getting priority to develop and evaluate explanations, Teacher as a moderator needed to make sure that students understood the objectives of learning and the issue for discussing. In the category of learners formulate, communicate, and evaluate their conclusion, she learned that small group discussion might be good to enhance students posting question and presenting ideas before and after investigation. Focusing on the teacher role in inquiry teaching, she realized that teacher as moderator was important to ask oriented question and motivate students' thinking. Moreover, she learned the moderator should evaluate students' learning process along the way of their learning in order to encourage, or strengthen the students' conception. If the students have misconception, the moderator could know during the formative assessment and could find out other teaching technique for students' changing their misconception.

2.3 Keaw's Classroom Practice

Keaw allowed the researcher to observe her teaching on the topic of "substances used in daily life" one week after the workshop. She was somewhat teacher-centered teaching in this lesson which some activities was inquiry aspects. Later, she could develop somewhat student-centered teaching in the "phases of moon" lesson during the modified lesson study.

2.3.1 Keaw's Initially Practice

This topic was about matter and properties of matter which is typically taught in the second semester. She conducted the lesson with 3 steps that were introduction, instruction, and summary. The objectives of this lesson were (a) investigate, discuss, classify different substances used in daily life, and (b) be able to selectively use these substance correctly and safety. These objectives were relevant to the expected outcomes of IPST curriculum in terms of two of three expected outcomes related to this topic. The other expected outcome which she did not include in the lesson was about making use of different types of substances.

A. The Level of Inquiry of Keaw's Practice Before the Modified Lesson Study

According to initial observation on Keaw's teaching her teaching was somewhat teacher-centered approach. Keaw started the introduction step by asking students to show products brought from house. She focused on students interesting but not scientifically oriented questions. However, the ways students learned still under teacher's direct the priority to get evidence. Her practice before the modified lesson study is illustrated in Table 5.4

In the introduction step, Keaw provided students with specific questions to be investigated. Students were excited about finding things in their products. They wanted to tell friends about what they found on their products. It was interesting for students to learn about things in their own households. However this activity was somewhat teacher-centered as students had opportunity to formulate their own questions.

Table 5.4 Brief of Keaw's classroom practice before lesson study

Steps	Classroom practice	Level of inquiry
Introduction	1. Teacher asked students to show the products brought from house	2
	2. Teacher asked students to notice their products with following points	
	- What kind of products?	
	- What do you found on the products?	
	3. Students answered these questions	
Instruction	1. Teacher asked students to discuss about the products and their use	3
	2. Students discussed in small group	
	3. Each member in the group presented the ideas to classroom	
	4. The head of each group concluded about the products and their use presenting in the group	3
	5. Teacher revised students knowledge by playing games	
	- grouping the products game	1
	- calling the products game	
Summary	Teacher summarized that the substance are around students' selves	1

In the instruction step, Keaw fostered students' interest in deepening their investigations. However, these experiences were not fully science investigations because students did not generate the questions or hypothesis about natural phenomena. Keaw's instruction in this step reflected a student-centered approach in three aspects. Firstly, she asked students to discuss their investigation and did not try direct students' questions to investigate. Secondly, students had to plan their work in groups, question group members, and exchange ideas about their investigations. Lastly, students formulated conclusions from the evidence with each member contributing with respect to the topic that teacher provided at the beginning. Student Group 3 was the first group to present the findings of their investigation. The following excerpt illustrates students sharing what they had learned

Student 1: “Our group would like to present the products. We have four drinking products to present today. The first is coffee. It will help people relieve sleepy. This product consists of Caffeine which is kind of addiction.”

Student 2: “This is the orange juice. It is good for health. We could drink it on our free time.”

Student 3: “This is milk. It makes our body strong and healthy. It makes our teeth stronger”

Keaw: “Could you tell friends how milk makes teeth be stronger?”

(Student 3 could not tell, but friends in the class told Keaw that there is Calcium in milk. Calcium can protect teeth.)

Student 4: “This is energy drink. It will help people to have more power for working.”

Student 1: “The drinking products in our group presenting both of advantage and disadvantage”

Keaw: “Could you tell more which products provide advantage or disadvantage?”

Student 1: “Mostly products are advantage except coffee. People can be addicted the coffee.”

Keaw: “You are right that coffee is disadvantage because of addict of Caffeine. You know the energy drink is disadvantage. It gives you power because of Caffeine also. The producer put lots of Caffeine in it. Therefore if you drink energy drink you will addict Caffeine. (Keaw’s teaching before lesson study: 17 Nov., 2006)

After every group finished their presentations, Keaw praised students on the a good job they had done on their presentations. She refined students knowledge by asking students to play games related to their investigations. These game was very fun for students. Keaw used activities to help evaluate students’ knowledge. However, it was a teacher-centered way to evaluate, because students did not have opportunity to be prompted to examine other resources and make connections to other resources or situations.

B. Keaw's Practice of the "Substances Used in Daily Life" Lesson Was Consistent with Her Narrative Knowledge

The researcher compared Keaw's practice to the narrative knowledge she developed in the workshop in order to gain insight the relationship between her practice and belief about teaching before the lesson study. The findings showed that her practice before lesson study had both aspects of teacher-centered and student-centered approaches. Majority of Keaw's practice was relevant to a teacher-centered approach. Her practice reflected Keaw's beliefs about the teacher's role as a coach for students and their learning, which was similar to her beliefs proposed in her interview before workshop. The student-centered approach reflected Keaw's practice in using students' conclude and communicate their own knowledge as illustrated in follows.

1) Students' Conclude and Communicate Their Own Knowledge (Knowledge of Instruction)

Keaw used small group discussion to enhance students' ability to present their ideas. This practice was relevant to the knowledge that she developed during case-based pedagogy reflection. She viewed herself as a moderator and motivator of student discussion and assessed students ideas after their presentation. Her practice in the "substances" lesson reflected the belief of her first metaphor, teacher as a six-side mirror. She gave opportunities for students to conduct their learning under the guidance of the teacher's consideration.

2) Content-Based Curriculum with Students Learning in Their Context (Knowledge of Curriculum)

Considering objectives and evaluation design, Keaw demonstrated curriculum knowledge of content-based design in which she followed the core curriculum. The objectives from core curriculum without any changes or additiona for students. However, the activity and media used in this lesson were more relevant to students and their context. Keaw designed the lesson so that students could learn science content from the things that they were familiar with. The assessment was conducted by in teacher's observing and evaluating on students ideas.

3) Teacher Feedback to Students' Conception Immediately (Knowledge of Subject Matter)

In this lesson, Keaw provided an opportunity for students to construct their knowledge of substances used in daily life. Students shared and presented their knowledge and understanding of these every day substance. Keaw was the person who assessed students' conception. She gave her feedback to the student immediately which was consistent on her reflected on the cases of "too many questions, too little time." She reflected teacher should moderate students to discuss, consider their answer, and help them to conceptual change by discussing.

2.3.2 Keaw's Practice during Lesson Study

Keaw's practice during the modified lesson study was revealed three points of analysis: translation of narrative knowledge into classroom; students' learning; and the things that Keaw learn from lesson study. The details of these findings are described below.

A. Keaw Translated Narrative Knowledge to Classroom Practice

1) Lesson Planning

Keaw kept the goals of lesson study in Radbumrung School in mind in designing lesson plans. The goals were (a) develop student construction of questions through 5E's instruction, (b) develop student knowledge according to science curriculum standards, and (c) develop student process skills. She choose the topic "phases of moon" as a lesson plan for the modified lesson study. The objectives of the phases of moon lesson were (a) observe and explain the moon in different positions, (b) explain the relationship between the earth and the moon according to phases of the moon, and (c) create a model of moon phases phenomena. The first two objectives were consistent with the expected outcomes of IPST curriculum on the phases of moon topic. The last objective she designed in order to develop students thinking about modeling the phases of moon. From the lesson plan "phases of moon" and discussion of the team, she presented knowledge of the following:

1.1) Designing Objectives Relevant to Student (Knowledge of Curriculum)

At the beginning of the modified lesson study, Keaw was not confident in designing lesson plans, because she used to following the instant lesson plan. She was nervous about designing objectives and activities for 5E instruction.

Keaw: "Do I have to design lesson plan? I used to follow textbook, it was very easy. If I have to design 5E lesson it must be more nervous."

The researcher: "Oh! It is not that nervous. We can adjust the objectives that presented in the text book to be more relevant to expected outcomes of core curriculum and our goals"

Keaw: "Therefore, the process of lesson plan development is that, firstly, looking at the learning standard, second, looking at expected outcomes, third, looking at our goals, and then create the objectives for the lesson plan, and finally, select the activities for each step of 5E (Keaw's discussion on the 1st meeting, December, 2007)

Keaw showed her lesson plan after meeting. Her lesson plan described the relationship between the earth and the moon correctly. She also connected the Thai calendar to this lesson. The lesson showed that she valued scientific knowledge and the Thai cultural context, as a means of enhancing students knowledge construction about the phases of moon.

1.2) More Confidence in the Phases of Moon Concept (Knowledge of Subject Matter)

Keaw mentioned that she had a good understanding of the phases of moon topic. The modified lesson study gave the her opportunity to design lesson plan by herself. She had to concentrate on understanding the content in order to design an activity that would enhance the objectives of the lessons, as she described as follows:

> When I started to design the phases of moon by myself, I was so confuse on the reflection to each position of moon. I took time for making understand on it. Now I feel more confident on the phases of moon concept. (Keaw journal, March, 2007)

1.3) Science Process Skill and Small Group Discussion (Knowledge of Instruction)

Keaw explained in the process of planning this lesson that she wanted to support students' thinking and their use of science process skill through 5E instruction. Keaw believed that students were motivated to think and take action by teacher. In this lesson she would be the facilitator to support her students' learning

> I keep our goals in mind. I focus my students to hands-on with science process skills on experiment in 5E. I want to improve them to be presenter of their ideas. I will support them by finding the nice activities, prepare the equipments, give help when they need, and give them some suggestion. (Keaw journal, March, 2007)

2) Teaching

In general, Keaw's teaching was somewhat inquiry oriented. Her practice was analyzed using the science teacher inquiry rubric (NRC, 2000; Beerer and Bodzin, 2004). The results reflect aspects of both inquiry and non inquiry as follows (Table 5.5)

Table 5.5 Brief of activities with level of inquiry of Keaw's teaching in grade 6/2

5E's	Classroom practice	Level of inquiry
Engagement	1. Teacher engaged students interest by singing songs about moon (*Duean Pen, Kuen Duean Ngaii,* and *Chan Ei Chan Chao*) 2. Students thought of more songs about the moon and sang their songs (The songs were presenting many shapes of moon) 3. Students drew the shapes of moon from their prior experience (students drew many shapes of moon)	4
Exploration	1. Student hands-on following the teacher's guideline for experiment	1
Explanation	1. Students constructed the phases of moon model according to their observation in experiment 2. Students explained their phases of moon model 3. Student and teacher discussed about explanation of each group	4
Extension	1. Teacher explained about Thai calendar which count the day by moon period	2
Evaluation	1. Students constructing the phases of moon model 2. Student individual observation report 3. Student working in group 4. Student evaluate their explanation	4

Table 5.5 shows how Keaw's practice was analyzed in terms of the science teacher inquiry rubric. Keaw's students thought about the scientifically oriented questions. She started the engagement step by catching students' interest with moon songs. She asked students to draw the shapes of moon from what they knew from songs or their experience. Students noticed that the moon

had many different shapes. They wanted to know why the moon had many shapes. Next, she provided the procedures for the students to conduct an investigation which was teacher-centered teaching. Then the students collected data by themselves and formulated their own explanation, consistent with student-centered learning instruction. She did not provide opportunities for students to connect their explanations. She was the disseminator of information about the use of moon phases in Thai calendar. However, she used a student-centered approach in evaluation involving on formative evaluation, a variety assessment tools, and student evaluated on their explanation.

3) Revising Lesson

After observing Keaw's lesson, team members including Keaw, Pim, and the researcher had a meeting for reflecting on Keaw's actions. Keaw felt that 5E inquiry could improve students' conceptions, science processes, and scientific mind

> It was amazing that the students understood the phases of moon and explained the correct concept. I think that students had more enthusiasm and happy in collaborative working. They were active for observing and creating the model for the phases of moon. They also presented very nice explanation on the phases of moon. (Keaw discussion after her teaching in 6/2, 21 Feb, 07)

The team identified two problems in Keaw's first teaching. The first was about taking too much time in engagement and explanation. In addition, there were too many students in the class which created a crowded situation for doing experiments. She decided to keep her teaching the same way for next classroom. There was nothing revise for this lesson.

4) Re-teaching in Grade 6/3

Keaw kept all activities in each step of 5E phases of the moon lesson the same. However, there were some differences in her practice in terms of questions and timing of the activities. These differences adjustments make by Keaw for keeping all activities of the phases of moon lesson happening on time.

B. Students Learning through 5E Phases of Moon Lesson

Keaw's teaching effected student learning in many ways which were relevant to the goals of the lesson study in Radbumrung School team. These aspects of learning were related to three aspects of inquiry. The first learning aspect was that students were prompted to formulate questions. The second was that students explained the moon in different positions and the relationship between the earth and the moon in terms of the phases of the moon. The last learning aspects concerned students use of science process skills which were; observing and recording data from an investigation, communicating within group for explaining, and creating a model of moon phases. The details of students' learning are described below.

1) Students in Grade 6/2

In the engagement step, students shared some alternative conception during their explanation about prior experience with shapes of the moon. For example, one student thought the shadow of earth hides the moon, the earth rotates the moon, and the moon receive light from sun.

Keaw:	"What do you notice for the moons that you drew on the blackboard?"
Students:	"They are different shape"
Keaw:	"Why do we see the moon in different shapes?"
Student 1:	"The shadow of earth hide the moon"
Keaw:	"Are there any other ideas?"
Student 2:	"The earth rotate around the moon"
Student 3:	"The moon receives different light from sun"
Keaw:	"Do you wonder what makes the moon have different shape?"
Students:	"Yes" (Keaw's teaching in 6/2, 21 Feb, 07)

In the explanation step, student created the phases of moon model. All groups of students could present the correct explanation of phases of moon. For example, the student group 1 was the first group volunteer to present. They brought their phases of moon model and explained in follow,

> When sunlight go to the position 1. We cannot see the moon, because we stand on different side of the sunlight. When the moon move to the position 2, we can see some part of the moon which sunlight shines to the angle of moon. (Student's explanation about phases of moon, Keaw teaching in 6/2, 21 Feb, 07)

2) Students in Grade 6/3

Most of the learning experience of the students in grade 6/3 was similar to those in grade 6/2. There was some interesting finding in this re-teaching. Students in grade 6/3 had different alternative conceptions about phases of moon. For example, they thought that the moon changes shape by itself, the cloud hide some part of the moon, and that the amount of sunlight effecting on the shape of the moon. In the explanation step, students explained their phases of moon models. In the elaboration step, Keaw extended students' knowledge in relation to the Thai calendar. She tried to explain the position of the moon in a cycle of one month, but made a mistake in shading the incorrect part on the moon. Students in the class asked her to correct it.

Conclusion of Keaw's Practice

Comparing Keaw's practice in the "substances used in daily life" lesson with the "phases of moon" lesson, her practice had shifted in student-centered approach. In the "substances used in daily life" lesson, there were some teacher-centered aspects of the lesson evident. These aspects were found in the introduction and at the end of instruction. At the beginning, students were directed by teacher to think about what they would learn. She asked students to exchange ideas in small group discussion. She was the moderator who gave opportunity for student presenting ideas and assessed students' ideas at the same time. At the end of the instruction, students did not have an opportunity to examine or connect their understanding with another resource. Keaw's practice in the "phases of moon" lesson reflected the higher practice of inquiry. The students prompted to formulate own question, create the model of moon phases, explain the moon in different position, and the relationship between the earth and the moon leading phases of the moon. Keaw's understanding of inquiry from her practice was relevant to her narrative knowledge on using a small group discussion, making clear on objective of activity before student learning, and using formative assessment. Some practice was developed beyond her narrative knowledge. She developed from the moderator to be the facilitator of students' learning.

Keaw was satisfied on the "phases of moon" lesson which induced students to become active in thinking and science skills, The lesson was successful in engaging students to answer the teacher's questions. There was evidence of raising key questions from students and evidence of their conversation with teacher and their explanations showed that students could improve their thinking skills through hands-on and mind-on investigation of the phases of moon lesson. They had a role in constructing knowledge through their curiosity about phenomena, observation through experimentation, making sense from the relation of factors and data results, discussion correct conceptions and evaluate on the conceptions. Keaw's role was more of facilitator who supported students' thinking and science skills. The conversation in small groups supported students sharing of ideas.

2.4 Keaw's Understanding of Inquiry after Lesson Study

Keaw wrote a second teaching metaphor and a classroom case after finishing her participation in the modified lesson study. Her second teaching metaphor was "teacher as what students' want." Her classroom case was "answering every question…How to do it?" The findings showed that her second metaphor and classroom case reflected many aspects of student-centered teaching.

2.4.1 Keaw's Second Metaphor

"Teacher as What Students' Want"

After I used 5E inquiry learning cycle, I found some changes on my instruction. I brought many techniques in teaching and many activities for each lesson unit and each step of teaching. I have learned to make my lesson to be interesting by naming it concerning to students' interest such as their favorite story. I think that it is the good start to attract to student. In engagement, I prefer to engage students to the lesson by game, songs, tales, and so on. My students gave good feed back of interesting to what they will learn in next activity. After that, I brought them to the lesson that containing with many activity such as demonstration and experiment. I gave them some suggestion or advice all the activities. I think that teacher should be anything that students want. I also do anything for my students' better learning. (After lesson study on March, 2007)

A. Students Choose Their Way of Learning with Teacher's Facilitation

Keaw's two metaphors demonstrated some change, and a focus on different aspects of teaching and learning. The first metaphor, "teacher as a six-side mirror" demonstrated her belief that the role of teacher is to reflect students learning. She looked at her students first. If she saw them make mistakes, she would give a hand to help her students. She did not describe how she prepared or facilitated students' learning. However, in her second metaphor, "teacher as what students' want," her role was described as more of a facilitator. She was more concerned with what was best for students' learning. She prepared many activities and media beforehand.

2.4.2 Keaw's Classroom Case

Keaw was asked to write her own classroom case after finishing the modified lesson study. She wrote about her own experience which she was impressed with and, therefore picked it to explain in her own narrative.

"Answering Every Question…. How to do it?"

I am a 28 years experience in elementary school. In 15 years past, I have taught science. I often started the first week of new semester by talking and making familiar with my students. I talked to them about how science looks like, how I (the science teacher) looks like. I told them that they have to think, talk, and practice on their own ideas. I like the presenter. However, it seemed that my students in every semester was same in some problems. They don't think, talk, or practice. It made me feel uncomfortable and worry so much.

I think that questioning is the first thing to help my student to think. I put questions in every step of 5E inquiry cycle. I could ask students any time and students could ask me or friends any time for expending their learning. This way is so different from my instruction in the past. I put questions only in the introduction step (she used 3 steps of introduction, instruction, and conclusion in her previous instruction). After I participated in the 5E inquiry learning workshop. I had more understanding and realized the important of questioning which motivates students to think about their own questions or answers. It will bring them to what they want to know. If they don't know that concept yet, they are activated to new searching the answer for their own questions.

My teaching responsibility is science teaching for 4 classrooms of grade six. In my experience, there were only 4-5 of 45-47 students always asking questions or answer questions. Other students were keep quiet like a robot. In this semester, I tried new idea to built enthusiasm to my students. I asked my students to ask only one question to me. It could be whatever, not focusing on science or academic question. At first, it seemed that I forced them to ask question. When they asked me, I answered them every questions, sometimes it is right answers, sometimes it is incorrect answers, sometimes it is just funny answers. However, this way could reduced the fare of presenting their idea. I noticed that they got more familiar to ask and answer questions. Sometimes, I told them that "Oh! I can't answer this questions, could you help me finding the answer?" Next day, my students bring the answer to me.

When students can questions to me, I start to help them to think more reasonable questions, or think before questioning. Students were enjoy to ask question to friends who presents in front of the classroom. Students were good listener, because they wanted to question the presenter. The presenters were sometimes worry about question. I gave help them to answer or give them opportunity to search the answer to tell friends in the next period. This is the most important thing that I want it happens in my science class. I don't focus much on content. I wants my students showing their potential on reasonable thinking, solving problem, and be good presenter. I think that Thai students are lack of reasonable thinking and low ability to present their creative idea. Therefore, teachers' concern to answer students' questions will be a good start for students thinking ability. I know that it takes too much time, but it is value for the results. I want to note about what I concern for my teaching.

1. I used 5E inquiry. I think that engagement is important for student learning. It helps teacher know students' readiness, basic knowledge, prior knowledge, and prior experience. If teacher could bring students' interesting, exciting, and curiosity, student will participate next activity very actively. The teaching in next step will be more comfortable, because students want to learn by themselves.

2. I found that students were not enthusiasm in learning before using 5E inquiry. Now they are better.

3. My school is big school 1,700 students, but it is built on small area. In each classroom, there are 40-45 students and sometimes 50 students. The school is

surrounded by community. It is in urban area, people mostly moved in to work. Therefore students are increasing so quickly.

4. My students were from different family. Many students were from poor family, separated family, worker family, and so on. They didn't get nice treatment from family, because family were earning money. Nobody took care of them after school time. Also around school area, there are many game center. Students played game. They preferred game center than school. The problem following was that they often absent the school.

5. My intension of teaching science. I want my students to be reasonable thinking person, talking and practicing on their creative ideas, and love learning for their better lives. (Keaw's classroom case, March, 2007)

According to her classroom case, Keaw had developed a better understanding of some aspects of inquiry.

A. Students Answering Themselves through an Investigation (Knowledge of Instruction)

Keaw's lesson was more student-centered approach. She learned to design inquiry aspects about students' thinking and presenting ideas together with develop their science process skills such as observing, questioning, and communicating. She learned to use questions for engaging students to be interesting in the lesson and asking their own questions for further inquiry. She planed and prepared various sources of media and activities to support the difference of students. She learned to designed lesson to be relevant to students interesting. These are her learning about knowledge of instruction which concerning on students differences.

B. Teacher Did Not Responding on Every Student, But Supporting Them with Variety Learning Activities (Knowledge of Self)

Keaw realized that teacher is the one of important factors in enhancing student construction of knowledge. She mentioned that teacher has to know students in many aspects such as ability, need, background, and learning style. Teacher couldn't response on every student, therefore teacher should support students with variety learning activity. To do this, teacher has to have view and belief on students' potential of learning.

C. Family is the Important Supporting Factor of Students Learning (Knowledge of Milieu)

Keaw reflect that students now a day were lose of interesting in learning. She thought that learning environment is important. She needed the cooperation from family to take care of students. Parents were not have time to provide students good taking care. Students were playing out at game center or did misbehave. They thought that study is not their favorite. Therefore it would be good if parents took care of their children after school time.

2.4.3 Things that Keaw Learned through Her Practice in Lesson Study

Keaw had improved her inquiry during participating in lesson study. The results showed that lesson study enhanced her to construct teacher knowledge that benefit for improving inquiry teaching. She had learned new teacher knowledge during lesson study that were knowledge of instruction and students, knowledge of curriculum, and knowledge of milieu.

A. Lesson Study Was Effective in Sustaining Teacher Development of Inquiry Lesson (Knowledge of Instruction)

There was evidence to suggest that the areas of improving inquiry instruction were affected by lesson study experience. Keaw was inquiry on preparing the questions, activities, learning media, and practice the procedures of 5E instructional model. Evidence of improving inquiry instruction was found in Keaw journal writing

To participate in lesson study, I have to prepare myself and study about the lesson. I was studying on science content, step of 5E inquiry and the appropriate activities in each step, prepare learning media in order to prevent from any errors happening in classroom. (Keaw's journal, March 2007)

B. Reflection Is Good Process for Improving Teaching (Knowledge of Instruction)

Keaw has learned that in each teaching, there were different problems. She realized that reflection during lesson study was beneficial for improving her teaching. She could prepare to face some problems from her own reflection on the previous action or suggestion from peers.

> Lesson study is opportunity for me to bring knowledge from workshop into real practice. I systematically planed and implemented the lesson to the two classrooms. I had to prepare lesson and myself. I was thinking on preparing activities, media, and students working. After teaching, I found some problems. I tried to solve it and got the suggestions from the observers. I felt more confident for implementing the revised lesson to the next class. (Keaw's journal, March 2006)

C. Knowledge of Curriculum

Keaw learned how to design the good lesson plan to improve student learning which more consistent for her students and their context.

> Before I implement the phases of moon lesson, I was planning and designing the lesson with peers. I tried to design it to be relevant to my students. The activities were selected to be relevant to the step of 5E inquiry. I concerned on students hands-on, questioning, and be enjoy on my lesson. (Keaw's journal, March 2007)

D. Knowledge of Milieu

Keaw thought that the lesson study provided the collaboration to improve inquiry teaching. The benefit for improving teaching was presenting during exchanging idea in lesson planning and suggesting after observation. She mentioned about the disadvantage of lesson study when the other came to see her teaching, she felt lack of freedom in her classroom.

> The advantage of lesson study is that we can exchange many good ideas for developing the lesson plan and advises for improving teaching for the next classroom. However, I feel a little uncomfortable on my freedom when peers observe me in my classroom. (Keaw's journal, March 2007)

Conclusion of Keaw's Understanding of Inquiry after the Lesson Study

The three important factors supporting student construct knowledge were from a) Keaw's concerning on encouraging students to think, question, and present their ideas, b) Keaw's role in facilitator which focusing student to be hands-on, and c) Keaw's concerning on students differences which teacher should well plan and prepare various sources of media and activities to support the difference of students. However she thought that there were some obstacles for her students' learning from poor family, careless family, and game-center around school.

2.5 Keaw's Growth after Participating in the Professional Development Model

Evidence of Keaw's learning and practice with respect to inquiry teaching during this professional development model showed that she had grown professionally, especially in terms of her understanding of part of curriculum, instruction, subject matter and self knowledge focusing on inquiry teaching. This evidence was presented in the 5E instructional workshop section and the sustained contact modified lesson study section. According to the data, Keaw demonstrated growth in understanding the inquiry concept and translating it to her own teaching. This could be seen from her practice in the classroom and her narratives of metaphor and classroom case. The components of Keaw's growth found in this study can be described as follows.

2.5.1 Keaw's Constructing Knowledge from Narrative during Workshop

Evidences from Keaw's analysis of 5E earth science instruction worksheet showed that she could construct her own knowledge of inquiry in terms of teacher's role and students' role during each step of 5E inquiry. This was very helpful for her in terms of thinking about the activities appropriate to support inquiry. It was consistent with a student-centered approach which stimulated students' to ask questions or hypothesis engage in, hands-on activities with discussion, connect ideas with new situations, and participate in a variety of assessments from the teacher and self. Other evidence that her growing narrative knowledge for inquiry concepts was the reflection worksheet on case-based pedagogy. After Keaw read and reflected on the two cases, she realized some strategies to enhance inquiry. She learned to support students in constructing knowledge and evaluating themselves by group discussion. She also learned that teachers should make sure that students understand the objectives of their activities. The process of assessing and giving feedback on students' ideas was also important for enhancing students inquiry learning.

2.5.2 Keaw's Change from Teacher-Centered to Student-Centered Was Related in Both Her Beliefs and Practice

The vidence from observation during lesson study showed that Keaw change her teaching from teacher-centered to student-centered. She brought her knowledge which she constructed during 5E workshop to her own practice. The evidence collecting during the process of modified lesson study showed that she incorporated many inquiry activities into every step of 5E, except the exploration and elaboration step where she used a more teacher-centered approach (see Table 5.5). She felt that students had limitations in terms of their thinking ability especially in designing their investigations. The activities that she designed for her inquiry teaching were translated from her narrative knowledge constructed after reflecting on the first case. She mentioned her translation of this narrative knowledge into practice in the following excerpt.

> I think that questioning is the first thing to help my student to think. I put questions in every step of 5E inquiry cycle….After I participated in the 5E inquiry learning workshop. I had more understanding and realized the important of questioning which motivates students to think about their own questions or answers. It will bring them to what they want to know. If they don't know that concept yet, they are activated to new searching the answer for their own questions. (Keaw's classroom case: March, 2007)

2.5.3 Keaw's Change Her in Teaching Was Reflected in the Narratives She Constructed after Practice

Great evidence of Keaw's changing view to be more student-centered was found in the second metaphor. Her first metaphor was "teacher as a six-side mirror" and the second metaphor was "teacher as what's students' want." Comparing her teaching metaphors, there were changes in her view of teaching. In the first metaphor, she realized students could select the way they learn under the direction of the teacher. In the second metaphor, she presented a more student-centered approach where students choose the way they learn and evaluate themselves.

In this metaphor, she saw the teacher had role in facilitating students' learning by preparing varieties of activities, learning media, and suggestions for students.

2.5.4 Keaw Expressed a Desire to Continue Inquiry Teaching in the Future

Keaw mentioned that inquiry was good in many aspects for students' learning. She reflected on her impression of how inquiry had improved students' understanding of content, presentation, and attitude. She wrote in her journal:

> In the next year, I want to continue the 5E inquiry. I thought that my students had improvement on their learning when I used inquiry. They had more understanding which I assessed from their worksheets. They had more enthusiasm which I saw from raising hands for questioning and answering. They had better in conclusion which I noticed from their report and mind mapping. (Keaw's journal: March, 2007)

Conclusion of Keaw's Growth

After Keaw participated fully in this professional development model, she constructed the understanding of inquiry and implemented 5E inquiry in her science classroom. She improved her instruction to be more inquiry through 5E inquiry steps. Initially, she realized that students feared to present ideas or ask question. She led them to learning with teacher-centered teaching. However, teacher-centered teaching was different from her first metaphor of teaching which seemed student-centered teaching. She realized that it would be better if students constructing their own ideas. Therefore she planed to help her students to be better in thinking and presenting ideas. The evidence from analyzing on 5E instruction and reflecting of written cases showed increasing of the understanding of inquiry. She also changed her teaching practice to be more inquiry with the new understanding of inquiry. She used questions for engaging students to be interesting in the lesson and asking their own questions for further inquiry. She encouraged students for their own explanation. She supported students to present their ideas and ask questions for discussion. She found that students had improvement on their leaning and getting familiar to create their knowledge. The evidence form journal entries of her practice, the second metaphor, and the classroom writing reflected Keaw's understanding of inquiry after participating had changed in teacher knowledge relevantly to inquiry teaching practice.

Cross Cases of Pim and Keaw

The findings were analyzed across cases to see the common patterns of development through this professional development. The patterns of development are described in terms of teachers' understanding of inquiry, the lesson plans with inquiry aspects designed by teachers' themselves, teachers' teaching supported students' learning to be more inquiry, and narrative knowledge impacted by inquiry teaching.

1. Teachers' Understanding of Inquiry

From the findings in the cases of both Pim and Keaw, there were two way of learning for both teachers in terms of their understanding of inquiry which supported them to develop the understanding of inquiry more consistent with the student-centered approach. These ways were learning through analysis of 5E earth science instructions and reflection on the written cases pedagogy.

1.1 Low Level of Inquiry Teaching Perspectives Initially

The findings of initial understanding of inquiry from interview and metaphor presented that Pim and Keaw had different understanding and beliefs of inquiry. Pim had the understanding of inquiry consistent with teacher-centered teaching in both interview and metaphor. While Keaw held the understanding of inquiry in the somewhat teacher-centered approach which contained low and high levels of some aspects of inquiry. Keaw's understanding of inquiry was consistent with teacher-centered teaching presented in interview. Her metaphor reflected her view of teaching in student-centered approach.

1.2 Aspects of Inquiry Developed from the Analysis of 5E Earth Science Instructions

The findings from the cases of Pim and Keaw showed that they had a similar understanding of aspects of inquiry teaching. From their analysis of 5E earth science instructions they presented similar and different understandings as follows.

1.2.1 Similar Understanding for Inquiry Teaching

In the engagement step, they thought that students' prior knowledge, students' interest and students' express on their prior ideas were important aspects for this step. They felt that the eacher should encourage students to think and be curious in this step. In the exploration step, both teachers agreed on using hands-on activity.

1.2.2 Same Goals for Students' Constructing Knowledge, but Different Level of Inquiry

In the explanation step, both teachers felt that discussion would help students express their ideas. Keaw focused on students' explaining by themselves, but Pim thought that students were too young to discuss by themselves. Pim thought that teachers should help students express their ideas with respect to the content. In evaluation step, both teachers mentioned evaluating students throughout the whole process of learning. But Pim was more aware of different evaluation tools for inquiry, concerning student-centered approach.

1.2.3 Same views of Students' Development of Understanding after Their Explanation

In elaboration/extension, the two teachers expressed the same views of developing of students' understanding. They thought about extending students' ideas with additional investigations and application to new situations.

1.3 Refining the Understanding of Inquiry through Case-Base Pedagogy

According to Pim and Keaw's understanding of inquiry through case-based pedagogy, there were two common patterns that emerged:.

1.3.1 Think about How to Use Techniques for Inquiry before Authentic Teaching in Classroom

The process of reflecting on the written cases enhanced Pim and Keaw's understanding of some aspects of inquiry. In the first written case, they had similar ideas of using the small group discussion. They refined their understanding of using discussion in the classroom by considering different points of views. Pim would use discussion as a tool to help students' conceptual change, while Keaw would use discussion as an opportunity for enhancing students' ability to express their ideas. In the second written case, both teachers discussed similar aspects of formative evaluation for enhancing student inquiry. They thought that it was necessary to assess students' alternative conception at every steps of learning. At this point, Keaw had more concern about the need for students to realize the objectives of activity beforehand so that students cloud think about their own works without copying others' work. Both teachers also thought that teachers should assess on product and process to develop the insight into the actual understanding of the students.

1.3.2 Express the Possibility of the Teacher's Role for Inquiry Teaching

Both teachers felt that the teacher should have role in helping students construct their own ideas through the questions. Pim thought about the role of facilitator who uses questions to explicate students understanding. Keaw thought about the moderator who motivates students in discussion. Keaw had more concern for making the lesson student-centered, focusing on students' potential to construct knowledge with less direction from teacher.

2. Teacher Inquiry Teaching in Authentic Classroom

Pim and Keaw taught with somewhat student-centered approach. They had the same patterns of activities in each step of inquiry. Most of their activities concerned on high level of inquiry, but some activities presented the feature of less student-centered teaching. There were some patterns of their developing of inquiry emerged from their authentic practice as follows.

2.1 The Lesson Plans with Inquiry Aspects Designed by Teachers' Themselves

The lesson plans which Pim and Keaw constructed for the modified lesson study were very similar in the pattern of activities. Their lessons started with activities to motivate students expressing their prior knowledge and thinking about questions or hypothesis for conducting further investigation. Next, students investigated their questions or hypothesis with the procedures which teacher provided for them. Then, students explained their understanding in group discussion with teacher's facilitating. After that, students had the opportunity to apply their knowledge in similar situations. Teachers provided the opportunity for evaluating during these pattern of activities in each step of 5E instructional model. The assessment tools were student presentation, hands-on and mind-on experiment, constructing models, worksheets, and collaborative group work.

2.2 Teachers' Teaching Supported Students' Learning to be More Inquiry Oriented

Pim and Keaw designed the inquiry lesson by considering teachers' need to improve students' thinking. They worked together on designing the activities in order to support students' development in thinking skills, science content, and science process skills. Similar evidence of students' learning was presented in both teachers' classrooms where students' formulated their own questions or hypothesis, explained their own idea, created predictions, make observations and record data, communicate the ideas, and create model. During the processes of learning, teachers assessed students work and the products from learning. Students also evaluated their own learning.

2.3 Impact of Narrative Knowledge on Inquiry Teaching

The narrative knowledge was reflected through Pim and Keaw's metaphors and case discussion had a similar impact on their teaching as follows:

2.3.1 The First Metaphors Reflected Learning Experience for Students in Low Level of Inquiry

Pim and Keaw did not design the lesson plan for specific needs, interests, or abilities of the students. They choose the lesson from textbook and followed all procedures. Pim's knowledge of students from metaphor "teacher as a gardener" reflected a belief in the low thinking ability of students, and teachers consequently to play more role the need for students' learning experience. Pim was the teller of information. Keaw's metaphor in "teacher as a six-side mirror" was more supporting students' learning, with her role of moderator who motivated students to think. But she was the only one who assessed the students' thinking. The evidence from the classroom observation before the modified lesson study showed that their practice was mostly consistent with this initial metaphor.

2.3.2 Narrative Knowledge from Case-Based Pedagogy Influenced the Development of a Higher Level of Inquiry in Some Aspects

According to Pim and Keaw's practice during the modified lesson study, they developed a high level of inquiry teaching in the same aspects. The level of inquiry depended on their concern for students taking action and responsibility of their learning. The knowledge of instruction constructed during case-based pedagogy was incorporated in their lessons. This included knowledge about students' prior knowledge, students constructing their own questions, students' discussion, and formative assessment. A higher level of inquiry was presented in engagement, explanation, and evaluation phases. The aspects of their high level of inquiry consisted of students formulating their own questions or hypothesis, students analyzing data, formulating their own explanation, and students evaluating their explanations by examining their original explanation.

2.3.3 The Strong Belief in Students' Low Thinking Ability Effected Low Level of Inquiry in Students' Planning Investigations

Eventhough Pim and Keaw showed growth in using inquiry for their lessons the during modified lesson study, they still had low levels of inquiry in students' planning investigations. They provideded procedures and protocols for the students to investigate. They thought that students were not able to think deeply or abstractly; thus, their own investigation would be too difficult for them.

Conclusion the Cases of Pim and Keaw

The inquiry concepts that Pim and Keaw utilized in practice after experiencing in 5E earth science inquiry and case-based pedagogy were similar to activities for student-centered supported inquiry. The evidence showed that case-based pedagogy enabled teachers to think more deep about their understandings. They brought their knowledge of inquiry concepts to solve problems which they faced in the cases. Both teachers accepted the new inquiry concepts and approved as a good technique for enhancing students' constructing knowledge. They used these new inquiry concepts in their own classroom and thought carefully about how to use them effectively for their students.

CHAPTER VI

FINDINGS OF TWO CASE STUDY TEACHERS FROM THAMMA SCHOOL

Introduction

This chapter presents the findings of Yanee and Boon, the case study teachers in Thamma School. In the workshop, they learned earth science concepts and the understanding of inquiry. After the workshop, they worked collaboratively with the facilitating from the researcher for developing and implementing the inquiry lessons in Thamma School. The context of the modified lesson study of Thamma School team were different from Radbumrung School team which described in the chapter five. The findings of Yanee and Boon are reported in two sections in this chapter. The first section describes each teacher's learning and practice in the topics of a) teacher's initially understanding of inquiry, b) teacher's understanding of inquiry during workshop, c) teacher's practice, and d) teacher's understanding of inquiry after lesson study. In the second section, the findings from both teachers are compared and presents about patterns of their changes. The last section of this chapter presents the common findings of four cases which themes of the findings presents about a) things to concern about teachers, b) things that teachers derived from the professional development model and c) the characteristics of professional development model enhance teachers' changes.

The Sustained Contact Modified Lesson Study Context of the Thamma School Team

The context of conducting the modified lesson study in Thamma School was different from Radbumrung School. There was no observation before beginning of the lesson study session, because teachers did not feel confident in having somebody take a look at their science teaching without preparing the lesson plan. Yanee and Boon were classroom advisors who had to teach many subjects for their own classroom.

Yanee taught science for grade 4/3 and Boon taught science for grade 4/1. According to the schedule of each classroom, Yanee's students had their science period before Boon's class. They could not exchange periods with other teachers. Therefore their roles were fixed, with Yanee doing the initial teaching and Boon in re-teaching. They taught the same earth science topics for their classrooms. They chose to work collaboratively on three lessons about earth crust, rocks, and soils.

As mentioned, in the context of Thamma School team, the modified lesson study was different from the one conducted in Radbumrung School. The steps of the modified lesson study of Thamma School consisted of designing the lesson, teaching by Yanee with member observation, revising of the lesson plan, and re-teaching by Boon with member observation. The schedule of the modified lesson study of the Thamma School team presents in Table 6.1

Table 6.1 The schedule of the meeting for the modified lesson study in Thamma School

Date and Time	Steps of the Modified Lesson Study	Activities
15 Nov 06 (3.30 - 4.00 pm.)	Planning	Meeting for introduction of lesson study
28 Dec 06 (3.00 - 4.10 pm.)	Planning	Meeting for designing the goals of the team
17 Jan 07 (7.40 – 8.35 am.)	Planing	Meeting for adjusting the lesson plans
24 Jan 07 (9.30 – 11.30 am.)	Teaching the earth crust lesson By Yanee (Grade 4/3)	Classroom observation by Boon and researcher
24 Jan 07 (3.30 – 4.00 pm.)	Discussion after teaching	Meeting for revising the earth crust lesson
25 Jan 07 (12.30 - 2.30 pm.)	Re-teaching the earth crust lesson By Boon (Grade 4/1)	Classroom observation by Yanee and researcher
25 Jan 07 (3.30 – 4.00 pm.)	Discussion after re-teaching	Meeting for evaluating the earth crust lesson
7 Feb 07 (8.30 – 10.30 am.)	Teaching the rock lesson By Yanee (Grade 4/3)	Classroom observation by Boon and researcher

Table 6.1 (Continued)

Date and Time	Steps of the Modified Lesson Study	Activities
7 Feb 07 (3.30 – 4.00 pm.)	Discussion after teaching	Meeting for revising the rock lesson
8 Feb 07 (9.30 – 11.30 am.)	Re-teaching the rock lesson By Boon (Grade 4/1)	Classroom observation by Yanee and researcher
8 Feb 07 (3.30 – 4.00 pm.)	Discussion after re-teaching	Meeting for evaluating the rock lesson
14 Feb 07 (9.30 – 10.30 am.)	Teaching the soil lesson By Yanee (Grade 4/3)	Classroom observation by Boon and researcher
14 Feb 07 (3.30 – 4.00 pm.)	Discussion after teaching	Meeting for revising the soil lesson
28 Feb 07 (9.30 – 10.30 am.)	Re-teaching the soil lesson By Boon (Grade 4/1)	Classroom observation by Yanee and researcher
28 Feb 07 (3.30 – 4.00 pm.)	Discussion after teaching	Meeting for evaluating the rock lesson

1. The Roles of Members in Thamma School Team

The roles of members in Thamma School team focused on Yanee and Boon who expected to be the investigators and reflective practitioners of their practice from the planning to evaluating of lessons by themselves. The researcher had the role as the "participant observer" which was benefit for enabling the deeper understanding. Therefore, the role of the researcher in Thamma School team School did not participate fully in terms of members' values and goals. The role of the researcher in the team was the facilitator who guide the process for teacher planning, observations, and reflection sessions.

2. Setting Goals for the Thamma School Team

Thamma School team, consisting of Yanee, Boon, and the researcher, met for conducting the modified lesson study according to Table 6.1. The first meeting was an introduction to lesson study. The researcher introduced lesson study to the team.

Yanee and Boon planned ahead, preparing for role, time, and students, because both teachers had to teach their own classroom the whole day. They needed to set times for observing each other. Initially, science schedules were fixed two hours a week. They decided to extend the science period from two hours to four hours a week in order to give time for students to do inquiry. In the second meeting, the Thamma School team set their goals for conducting the modified lesson study. The goals of this team were developing students inquiry through science process skills and developing students ability to express their opinion. The team expected that the students would be the one who would use science process skills to inquire. Moreover, they hoped that students should would express their opinions to others with the logical explanations, rather than just follow others without consideration.

3. Strategies to Achieve the Goals

In the second meeting, the team agreed to use two main strategies in helping the students to achieve the goals. The first strategy was incorporating science process skills in the 5E inquiry lessons. The second strategy was using collaborative work to enhance students' sharing of ideas. However, there was some difficulty in locating the needed science equipments. Thus Yanee was worried about setting up the experiments. Both teachers also expressed concern because the students were not familiar with expression opinions in the classroom.

4. Preparing the Lessons of the Team

The team met at the third meeting to prepare lessons of the team. Yanee and Boon worked together in designing5E inquiry lessons. They named the unit "The secret of the earth crust." This unit consisted of three lessons: "the components of earth's crust," "rocks," and "soils." They brought the designed lessons to the team for discussing how to adjust and improve the objectives, activities, learning materials, and assessment tools.

The Case Study of Teacher's Learning and Practicing through the Professional Development Model

1. Case 3: Ms. Yanee

1.1 Yanee's Initial Understanding of Inquiry : Teacher-Centered Teaching

Evidence from interview and Yanee's first metaphor of science teaching prior to participation in professional development was teacher-centered. She felt that school did not have enough science equipment and students had low thinking abilities. Therefore, her science teaching did not concentrate on science content and science process skills as she commented as follows:

1.1.1 Yanee's Interview

The initially interview of Yanee's current teaching and her understanding of teaching revealed that she was a teachers who used teacher-centered teaching. She did not write science lessons. She organized learning experiences following the textbook, focusing on simple activities and reading. The assessment for student learning was concentrated on students worksheets, group work, and tests.

A. Beliefs about Text Book, Available Learning Materials, and Ability of Students

Yanee had never written any science lesson plans. She used the instant science lesson plans from her textbook. The processes of selecting learning experiences for her students were as follows. First, she analyzed the core curriculum and expected outcomes of science strands. Next, she chose the activities from textbooks which was relevant to the expected outcomes from the core curriculum. Then, she followed the objectives and activities in that text book as she mentioned as follows

> I don't write science lesson plans, because we don't have science material in our school. I used the instant lesson plan which was relevant to the expected outcomes from the core curriculum. We sometimes put more expected outcomes in some part that suit for our context. In some part which more focus on higher ability of the students, we might cut out, because our students could not reach that too higher expectation. (Yanee's interview: July, 2006)

B. Science: A Simple Experience with Extensive Assessments

Yanee said that she conducted lessons in three steps: introduction, direct teaching, and assessment. She used materials from things and the environment around students. She liked to take students out to learning resources such as the zoo, museum, and nearby forest. She assessed students during the semester with variety of assessment tools such as reports, mini-tests, products, and mind-maps. At the end of semester, she used summative tests. Normally, she focused on science activities which were easy for her to prepare such as observation and easy experiments. She described her view of assessment as follows:

> I divide the assessment into summative and formative assessment. I give 30 scores for summative assessment on the test. Other 60 scores is depend on the variety assessment such as report, mini-test, produce product, and mind-mapping. I feel that students are happy on learning, because they don't need to read text book for the test. They are good at working on searching data and planning their group work. (Yanee's interview: July, 2006)

C. Students Were Weak in Content, Because of Simple Science Experience

Yanee indicated in her interview that, she prepared simple learning experiences in science, so students did not have opportunity to develop systematic science process skills. They just followed the activities which were presented in textbooks. A disadvantage in her school was the lack of science equipment; therefore, she thought she chose only simple activities if she couldn't find learning materials for the students. She realized that students could not improve their content through the simple experiences on science. Yanee commented,

> My students could not get good score on science content. They have low ability in thinking. They are happy to learn on simple activities and variety of assessment tools, because they don't need to read text book for the test. I am worry that they will face some problems if they learn in higher level which is focusing on science content. (Yanee's interview: July, 2006)

1.1.2 Yanee's Teaching Metaphor

Yanee's belief presenting in her first metaphor "teacher as a magician" was not consistent with inquiry teaching. She believed in teacher was the person who gave knowledge to students.

"Teacher as a Magician"

> I think that students are my children whom I have to take care always. From my experience, teacher's responsibility have never finished even students are graduated. Many students come back to teacher again for asking help. It is important of high service mind and spirit to be teacher which is not easy to do. That's why I think about teacher as a magician. The main role of teacher is that teacher have to know the contents and know how to transfer knowledge. Moreover, teacher have to love and be mercy to all students. It looks like the role of parents to take care children. When students get sick, have problems, or behave unpleased. I have to give a hand for helping them. I hope that my students will grow up to be good citizen in the society. In my opinion, teacher could metaphor as parents, psychologist, doctor, nurse, police, or coach. Therefore teacher as a magician is the best metaphor. I am proud to be teacher. (Yanee's the first metaphor: 11 Nov., 2006)

A. Students Were the Knowledge Receiver (Knowledge of Instruction)

Yanee mentioned that "the main role of teacher is that teacher have to know in content and know how to transfer knowledge." She used the word "transfer" which is consistent with teacher-centered teaching. According to her metaphor, Yanee believed that the teacher was the holder of knowledge and gave it to student. She also thought that teachers should help students with many things. She saw teaching as more than just disseminating content. She believed it was important to pay attention to the "whole" child. Therefore the word "transfer" was used to mean the teacher as giver knowledge and students as knowledge receiver. Yanee also felt that the teacher had many other roles, as well.

B. Teacher Controlled Students' Learning (Knowledge of Self)

Yanee thought about many aspects of the teaching role, such as psychologist, medical doctor, parent, police, monk, and coach. It was apparent that they were mostly about control students' learning which supported teacher-centered approach. An example of the teacher's role in controlling students is evident in Yanee's comments, "students are my children whom I have to take care always," "parents take care children," and "I give a hand for helping them."

Conclusion of Yanee's Initial Understanding of Inquiry

Yanee's initial interview and her "teacher as a magician" metaphor reflected view on teaching where the teacher was the person who transferred knowledge to students. The students were the knowledge receivers and got all help from her. Moreover, the school context of lacking learning media made her lesson weak for inquiry. In additional, her view on the low ability of students effected to her setting for learning experience depending on teacher which was consistent with a teacher-centered approach. The reference to magician was the idea that, she had to do many things to direct students, so needed a lot of "tricks" to accomplish that.

1.2 Yanee's Learning during the Workshop

Evidence from field notes, journal entries, analytic 5E instruction worksheets, and case reaction revealed that Yanee learned earth science contents and inquiry teaching focusing on strategies, techniques, and solution for inquiry teaching in actual classroom.

1.2.1 Yanee's Learning through5E Earth Science Instruction during the Workshop

Yanee indicated in her journal entries after participating 5E earth science instruction that she had better understanding of both earth science content and an understanding of inquiry. In terms of earth science content, she identified that she had learned about rock classification, characteristics of rocks, cloud formation, types of clouds, benefits from watching cloud, the process of erosion and weathering, physical and chemical weathering, and wind direction.

Yanee indicated that she could construct science knowledge by doing hands-on activities. She always joined the discussion after the activities. For example, nobody knew about the difference between the rocks and minerals at the beginning of the rock lesson. Later, Yanee could described the difference between rocks and minerals after she completed the "rock jigsaw." Yanee's conception about the difference between rocks and minerals was presented as follows.

Researcher: "Do you know the difference between rock and mineral?"

Yanee: "Mineral is luster, but rock is dull"

Researcher: "That's good idea, but I would like you to tell me again after playing the rock jigsaw."

Participants were asked to engage in an activity which the researcher named it "rock jigsaw" Participants spent playing minerals on a jigsaw puzzle to form various rocks. After that, they discussed the activity. Yanee commented as follows:

Researcher: “Can you tell me how different between a rock and mineral?”

Yanee: “Rocks consist of many minerals which make different grains in rocks”

Researcher: “Does the rock contain only one mineral?”

Yanee: “No, one mineral is meaning that it is a mineral. Rock is more than one mineral”

After that the participants were asked to observe rocks and make classifications of rocks. Yanee could identify some of criteria for rock classification, but she could not finish the classification by herself. All participants and the researcher discussed for making rock classifications on many criterion.

Researcher: “What are the common characteristic of rocks that you could observe?”

Pim: “Color… some rocks are light and some are dark”

Yanee: “Grain size… some rocks have the fine grain, some have the big grain”

Moreover, Yanee could explain her understanding in her own words in other topics of earth science. An examples of Yanee’s understanding about cloud formation and types of clouds are follows.

In the explanation step of the 5E inquiry cycle, Yanee was asked to describe the cloud in the bottle and explained the process of cloud formation. She explained “The cloud in the bottle is similar the fog in the morning. When we squeezed the bottle, the pressure and temperature were increased. The vapor could be more saturate in the air. The smoke from match created the core for clouds.”

In the elaboration step of the cloud lesson, Yanee also explained the types of clouds that she had learned “Cumulus is the cotton ball like. It stays in the lowest level in the sky. Stratus is like layer. It stays in the medium level in the sky. And Cirrus is the feature like which stays in highest level in the sky.”

1.2.2 Yanee Developed an Understanding of Inquiry through Participation in the 5E Earth Science Inquiry Instructions

In the engagement step of the 5E inquiry cycle, Yanee emphasized the need to motivate students by being enthusiastic. She liked to bring toys and cartoons for engagement. She noted,

> I think that using cartoon which the interesting situation was good to motivate students to wonder and enthusiasm to inquiry for the answer of the situation (worksheet No.3). The toys such as wind mill, wind bell, and wind vane were attractive for students' interesting on the lesson and enthusiasm of how them works (worksheet No.5). (Yanee's analyzing lesson worksheets: Nov., 2006)

In the exploration step, Yanee realized that hands-on activities involving experiments and searching for data helped students construct their own knowledge. However, she focused on the teacher role in leading students in hands-on activities. She explained,

> In exploration step, teacher prepared activities for students with the guide dance or demonstrate (worksheet No.3). Students constructed their own knowledge through hands-on with the group collaboration (worksheet No.4). (Yanee's analyzing lesson worksheets: Nov., 2006)

In the explanation step, Yanee expressed the view that students should be the narrators of their knowledge. She felt that the teacher should join the students' discussion or facilitate students by providing documents with additional information to further correct understandings. She commented,

> Discussion of the students was important for them to clarify their own knowledge. Teacher helped them during discussion or prepared more information which students could search for the correct understanding (worksheet No.4). I thought that it would be more advantage for teacher to

> assess students knowledge on the mini-test after this step (worksheet No.5). (Yanee's analyzing lesson worksheets: Nov., 2006)

With respect to the elaboration/extension step, Yanee realized that this step was designed to have students refine their understanding of a concept or to connect students' understanding to other situations with their own explanations. Yanee explained,

> Activities in this step helped students to learn in additional of what they explain in explanation. Activities helped them to see the benefit of their knowledge in real life (worksheet No.3). Students were asked to design the way to protect weathering and erosion which connected students' knowledge to the real life (worksheet No.4). (Yanee's analyzing lesson worksheets: Nov., 2006)

In terms of the evaluation step, Yanee mentioned the importance of formative assessment which should be used to assess the learning process in every step. She felt that both teacher and students had roles to assess learning. She suggested for evaluation the idea of using pre and post tests to see the development of students. She clarified.

> There were the assessments in every step of 5E inquiry instructions. The instructor assessed the participants and the participants assessed themselves to see the understanding which could be add or change for better understanding in the next step. (worksheet No.5). The assessment in the activities were mostly observation and produce product (worksheet No.4). I think about pre and post test would help teacher to see the development of students (worksheet No.5). (Yanee's analyzing lesson worksheets: Nov., 2006)

1.2.3 Yanee's Narrative Knowledge through Case-Based Pedagogy

During the workshop, Yanee was asked to reflect on two written cases containing dilemmas of inquiry teaching. The dilemmas were about techniques for supporting students' questioning and conceptualizing science knowledge and assessment for the inquiry learning approach. Yanee reflected on her narrative understanding of inquiry through these dilemmas as follows.

A. Small Group Discussion: The Way to Challenge Students Thinking and Encourage Them to Present Ideas

In order to provide opportunities for all students to participate in discussion, Yanee suggested using small group discussion before bringing all students to the whole class discussion. She explained,

> In the case of some students were shy to present idea, I prefer to use small group discussion before bringing them to classroom discussion. I think students could exchange ideas in small group better than in large group. (Yanee's the first case reflection: 11 Nov., 06)

B. Scaffolding Students' Conceptions from Their Alternative Concept

Yanee thought that alternative concepts presented during discussion could happen. She explained that she would not correct the alternative conception for students. Rather she would encourage students to continue their discussion. She felt that that the correct concept would be presenting by other students.

> I will ask students to explain why they have the alternative conception. Then I will ask other students to show other ideas. Finally the class will have the right conclusion (Yanee's the first case reflection: 11 Nov., 06). Teacher could provide more works for students to help them correct their alternative concept such as mind-map, produce products, report, and science project (Yanee's the second case reflection: 11 Nov., 06)

C. Teacher as a Moderator on Motivator

Yanee reflected on the first case which presented a dilemma about use of questions to help students understand scientific concepts. She suggested her role was to ask questions in order to motivate students. She also felt that teachers need to develop awareness of important issues in order to evaluate students' learning. She commented,

> In the case of no time for all students' discussion, I will choose some group to present idea and ask other groups to extend knowledge from the presenting group to save time. (Yanee's the first case reflection: 11 Nov., 06)

D. Students Describing of How to Work

Yanee thought that the teacher should assess students' understanding their products throughout the instructional process. This idea was relevant to authentic assessment, which assess would be mirrors the work of students. It needed teachers and students to assess the whole process of working.

> The teacher should assess students learning after teacher conducts teaching process in every steps. Then teacher can ask students to present their product and learning outcomes. (Yanee's the second case reflection: 11 Nov., 06)

Conclusion of Yanee's Understanding of Inquiry during Workshop

While participating in the 5E earth science lessons, Yanee constructed earth science content knowledge by doing hands-on activities. The discussion following the hands-on activities enhanced Yanee's mind's-on, connecting things she had done with real phenomena. The 5E earth science lessons not only enhanced Yanee's construction of earth science content, they also supported her ability to realize the aspects of inquiry teaching that took place in each step of5E instruction. She had an opportunity to be a reflective practitioner through what she experienced with the 5E earth science lessons. She could explain the teacher's role and student's role in an inquiry approach. Her understanding of inquiry were refined for more insight of using inquiry in classroom by reflecting on cases. She understood the inquiry techniques for how to support students questioning and conceptualizing of science knowledge by using small group discussion and scaffolding students' understanding around their alternative concept. She mentioned her role as a moderator in supporting students' sharing of ideas. In terms of assessment, she emphasized the need for students to describe their products explain how they work, and produce something. Her illustration of supporting student learning was consistent with a more student-centered approach.

1.3 Yanee's Practice: Changes to Somewhat Student-Centered Teaching

Yanee and Boon did not write science lesson plans. They set the science learning experience for students with the procedure in their mind or by just following the textbook. They were not confident enough to permit the researcher to observe their teaching practice before the modified lesson study. They felt they needed to prepare themselves for inquiry teaching in the modified lesson study. Therefore a change of practice with respect to inquiry teaching of the Thamma School team was noticed with each implementation of lesson plans of the modified lesson study.

This section illustrates Yanee's practice inquiry teaching, with respect to her use of the 5E instructional model. Her practices were traced in the process of the modified lesson study which consisted of lesson planning, teaching, and revising lessons. Moreover, student learning was described to ascertain the effectiveness of her inquiry teaching practice. Finally, evidence from discussion, journal writing, and interviews conducted during the modified lesson study were interpreted to see Yanee's patterns of development in inquiry teaching.

1.3.1 Lesson Planning

Yanee took responsibility to write the first draft of the lesson plans. She wrote three lesson plans which were about the topics of earth's crust, rocks, and soils. These topics were in the main unit of "the secrets of the earth crust." The objectives of this unit were divided into three learning domains of cognitive, psychomotor, and affective domains. The objectives in the cognitive domain consisted of (a) describe the components of earth crust, (b) classify the types of rocks and soils, (c) explain the processes of rocks and soils formation, and (d) describe the benefits of rocks and soils. The objectives in the psychomotor domain were (a) perform science process skills and (b) design a presentation of findings from investigation. The objectives in the affective domain emphasized (a) explain the importance of natural resources and propose the conservation of natural resources, (b) interact with others by discussing, questioning, arguing, and criticizing, and (c) help the team in collaborative work with happiness.

A. Small Group Discussion Enhancing Students' Collaborative Work and Their Ability to Express Opinions (Knowledge of Instruction*)*

Yanee proposed to use small group discussion as a strategy to enhance students interaction with others. She realized that her students were not brave enough to express ideas, therefore discussion in small groups would help them develop confidence in their ideas. Yanee explained

> My students were not familiar to express opinions. I think small group discussion will help them to work in group. They will have more confident. After that, we could ask each group to present opinions to others. Then we let the students to exchange ideas between group. (Yanee's discussion during the first meeting: 28 Dec., 2006)

B. Rubrics Help Teachers to Evaluate Student Learning (Knowledge of Instruction)

Yanee designed rubrics to help assess the students' learning. In her previous interview, she indicated that mostly assessed students with tests. She described on her idea to use rubrics in the evaluation step as follows.

In our lessons, we need to observe students' behavior. I think that we could use rubrics as criteria to see and give score to them." (Yanee's discussion during the third meeting: 17 Jan., 2007)

1.3.2 The "Earth's Crust" Lesson

The Thamma School team prepared three lessons designed by using the 5E instructional model. Yanee implemented these three lesson in the first round of teaching. Boon responded by re-teaching after consolidating ideas discussed after Yanee's teaching. There were 30 students in grade 4/3. Yanee was the advisor of this class. She had the responsibility for teaching many subjects including science. Students sat in fixed group. There were five groups with six students. The advisor's table was settled behind the classroom. The findings of Yanee's practice is described as follows.

A. Yanee's Teaching on the "Earth's Crust" Lesson

According to the science teacher inquiry rubric, (NRC, 2000; Beerer and Bodzin, 2004) Yanee's teaching contained some aspects of inquiry, but not all aspects of inquiry. The level of Yanee's inquiry teaching is presented in Table 6.2 and reflects the interpreted that her teaching was somewhat inquiry in nature.

Table 6.2 Brief of activities in "the earth's crust" with level of inquiry of Yanee's teaching in grade 4/3

5E's	Classroom practice	Level of inquiry
Engagement	1. Students observed and presented what they know or what to know from the earth model and map	4
Exploration	1. Students explored the earth crust on the school with small guidance from teacher in the worksheet. They brought their interested things, rocks, or soils to the class	3

Table 6.2 (Continued)

5E's	Classroom practice	Level of inquiry
	2 Students recorded what they observed and classify their interested things into group of "organism" and "non-organism"	
Explanation	1. Students presented the group findings of the area that they observed and the classification of their interested things 2. Students and teacher discussed the common understanding of the school area (flood plain)	3
Extension	1. Students and teacher discussed for others earth crust found in other regions (such as mountain, desert, grass plain, valley, glacier and so on)	3
Evaluation	1. Students creating the book "My Earth" from the paper which was cut and put in different level to see dimension of each scenery of earth crust 2. Student working in group and worksheet 3. Student expressing opinion during discussion 4. Student evaluating their explanation	4

1) Students in Grade 4/3 Learning about the "Earth's Crust" Lesson

Yanee taught the "mystery of the earth's crust" unit which consisted of three lessons. The students in grade 4/3 were enthusiastic about investigation. They were engaged and curious about things around them. They were asked to described what they had learned. Inquiry learning was a new experience for Yanee's students on inquiry learning.

The patterns of students learning were interpreted on the basis of classroom observations. These patterns showed the effectiveness of Yanee's teaching in relation to students' learning about the earth's crust lesson.

1.1) Teacher Engaging Students' Curiosity

In the engagement step of the 5E inquiry model, Yanee brought a map and earth model to the classroom. She noticed students were excited. She started the lesson by finding out about students' prior knowledge of the earth.

Yanee: "Do you notice any things new in the classroom?"
Students: "The earth map and model"
Yanee: "I would like you to observe the earth from the earth map and earth model. You should observe the color presenting on the map and model. Don't forget to noted it."

After students observed the earth map and model for ten minutes, Yanee and students discussed what they had observed.

Yanee: "This is the geographical map. The color presenting on the map tell you about the height of geography. Can you tell me … what the yellow represented?"
Students: "Mountain, Valley"
Yanee: "What's the color representing the plain?"
Students "Green"
Yanee: "Which cover the most area on our earth between ocean and land?"
Students: "ocean"
Yanee: "These were the earth crust that you observed from the model. Now, I would like you to observe the real earth crust. Let's see how the earth crust around our school look like?"

1.2) Students' Alternative Ideas on the School's Area

In the exploration, explanation, and extension step, Yanee distributed a worksheet for students to use while collecting data which they observed around the school yard. After 15 minutes, the students came back. Yanee started a discussion so that students could exchange explanations from their investigation. Students noted many things that they found around the school such as soil, rocks, paper, ants, trees, flowers, dogs, and so on. Most of students could distinguish between organisms and non-organisms. However, there were some alternative concepts presenting in students' explanation. The following explanation was from the students group 2.

> Students group 2: "From the observation on the school's area, we found the organisms that were birds, dogs, ants, and trees. Non-organism that we found were rocks, soils, dried tree. We thought that the organism and non-organism doesn't have any impact on each other, but they made the environment to be plentiful. (The explanation of group 2: 24 Jan, 07)

1.3) Teacher Connected Students' Findings to a Common Discussion of the School's Area

Yanee connected students' investigation to the prior knowledge, and observations of the earth model. Yanee tried to end this step with the concept that the area in central of Thailand is the flood plain. However, students didn't note much about the characteristic of plain. Therefore Yanee tried to used questions rather than telling the fact to the students.

Yanee:	"Think of the earth model in this morning, if we compare the area of our school, what is the color could be represented?"
Students:	"Green"
Yanee:	"What are the characteristic of our school?"
Students:	"The plain"
Yanee:	"Is there any mountain?"
Students:	"No"
Yanee:	"Then we get the conclusion that our school is in the flood plain"

B. Revising the "Earth's Crust" Lesson

After Yanee's teaching of the earth crust lesson, the Thamma School team including Yanee, Boon, and the researcher discussed the advantages and disadvantages of practice lesson as follows.

1) Reflection on the Success of the Earth's Crust Lesson

1.1) Yanee prepared herself for the lesson and learning material. She encouraged her students with smiling, nodding, and talking while they were expressing opinion, presenting, and answer questions.

1.2) Students presented enthusiasm during investigation. They had the opportunity to formulate what they wanted to know, conduct data collection, data analysis, and make conclusions. However, they had little chance about their own investigations. Sometimes Yanee made the conclusions for the students after they presented their investigations, because she felt that students were not good at making conclusions.

1.3) Student group works in Yanee's classroom was partially successful. The team noticed that there were only two groups who could work collaboratively. In the other three groups only some students were taking responsibility for work.

1.4) Students' interaction was successful in terms of students' expressing their opinion. In terms of questioning and critique, the team member did not observe much in Yanee's classroom.

2) Reflection on What Could Be Done to Improve the Earth's Crust Lesson

The team discussed things that could be done to improve the earth's crust lesson. The team would keep going with the tasks for student group work. They decided that science process skills needed more emphasis in the lesson. The team adjusted the lesson focusing on enhancing science process skills for students as follows.

2.1) Boon gave a suggestion to improve the engagement step. He said that teacher should ask students to interpret what they noticed on the earth model and map in order to better see their prior knowledge. In the exploration step, he suggested that the teacher should remind students about how they needed to prepare for things. For example, he said that teacher should ask students to revise their plans for the investigation.

2.2) Yanee suggested that they should do something to make it easier for students to think about other scene of earths crust. She suggested that team should bring pictures of the earth's crust and many different scenes during the extension/elaboration step.

2.3) The researcher supported Yanee's suggestion for using a matching game to engage students' interest on other scenery of the earth's crust, followed by a teacher discussion with students.

2.4) Yanee was asked to give time for students making conclusion by themselves.

Conclusion of Yanee's Practice of the "Earth's Crust" Lesson

Yanee's practice of the "earth's crust" lesson reflected some inquiry aspects such as developing students' curiosity about the earth's crust, letting students' investigate their school area, student self evaluation of their explanations and extending students' knowledge of the school area to other scene of the earth's crust around the world. However, Yanee's had some practices which were less student-centered, during the discussion which she sometimes told the important points instead of students.

1.3.3 The "Rock" Lesson

A. Yanee's Teaching on the "Rock" Lesson

According to the science teacher inquiry rubric, (NRC, 2000; Beerer and Bodzin, 2004) Yanee's teaching in the "rocks" lesson contained some aspects of inquiry, but not all aspects of inquiry. The level of Yanee's inquiry teaching presents in Table 6.3 which was interpreted that her teaching was somewhat inquiry.

Table 6.3 illustrated how Yanee's students participated in the "rocks" lesson. Her teaching contained some aspects relevant to high levels of inquiry. The activities of engagement and evaluation represented the highest level of inquiry. In the engagement step, Yanee prompted students to think about questions on rock. Students were asked to choose things which they thought to be rocks from a variety of hard things. They had to explain their reason and their rock definition. In the exploration step, students had opportunities to investigate rocks. They observed and recorded what they saw. They classified rocks with their own criteria. In the explanation step, the activities were somewhat inquiry. Students referred groups of rocks from their investigation. Then, they exchanged ideas and reported the group's findings to the class. After that, teacher prompted them to think about scientific criteria for classify the rocks and led them to a discussion of igneous, sedimentary, and metamorphic rocks. The extension/elaboration step was somewhat more of a teacher-centered approach. The teacher expected students to expand their knowledge of types of rocks in terms of the origin of each type of rocks. The rock formation concept was abstract for students. Therefore, teacher used a demonstration to facilitate students' understanding by asking them to match what they observed from the demonstration to the key words of rock formation which the teacher provided. In way, Yanee was the person who identified related scientific knowledge for the possible connections to students' alternatives explanations. The evaluation step was a high level of inquiry, because students evaluated their own knowledge with a variety of assessment tools.

Table 6.3 Brief of activities "rocks" with level of inquiry of Yanee's teaching in grade 4/3

5E's		Classroom practice	Level of inquiry
Engagement	1.	Students explained prior knowledge through activities choosing rocks from the hard things with the definition of "rock" in their opinion.	4
Exploration	1.	Students observed and drew the picture of rock which they collected in the school.	4
	2.	Students in each group classified rocks which teacher prepared from the rock collection box.	
Explanation	1.	Students concluded the groups of rock from their investigation.	3
	2.	Students and teacher discussed on the findings of rock classification and made the common understanding on the three groups of rocks following the scientist classification.	
Extension	1.	Teacher demonstrated the experiment on the formation of the rocks. The experiment was showed how the crayon (representing rock) changed by heat and compaction.	2
	2.	Students discussed what they noticed from the demonstration with the key words	
	-	the rock group 1: cooling from lava which spread out along the earth's fracture	
	-	the rock group 2: under high pressure and temperature for transforming	
	-	the rock group 3: sediments piling up and compacted under pressure	
Evaluation	1.	Students creating the model of rock formation	4
	2.	Student rock classification worksheet	
	3.	Students working in group	
	4.	Students expressing opinion during discussion	
	5.	Students evaluating their explanation	

B. Students in Grade 4/3 Learning on the "Rock" Lesson

After Yanee's taught the rocks lesson, the Thamma School team including Yanee, Boon, and the researcher discussed the advantages and disadvantages of the practice rock lesson as follows:

1) Students' Prior Knowledge of Rocks: Rocks Are Hard, Striped, and Many Colors

In the engagement step, Yanee challenged students with unknown objects. There were three objects: a rock (Andesite), mineral (Calcite) and a big piece of cement. Students could identify the rock and the big piece of cement. They thought that Calcite was glass. The following conversation provides insight into the students' prior knowledge of rocks.

Yanee:	"What is this object?"
Waroot:	"Striped rock"
Yanee:	"How did you know it is rock?"
Waroot:	"Because it is hard and it has stripes"
Yanee:	"Can you tell me what the rock look like?"
Somjit:	"The rock is hard"
Yanee:	"What do you see in the rock?"
Juntra:	"Many colors… black, yellow, and brown?"
Yanee:	"Does rock has all same color?"
Juntra:	"No…some rock has light color, some rock has dark color"
Yanee	"That' s because rock contains many minerals inside"

2) Students' Categories of Rocks

In the exploration step, Yanee let the students observe nine rock samples with the two general criterion provided – color and grain. Students noted what they observed and created their own categories of rock. The following table (Table 6.4) are examples of the categories of rock from students' investigation.

Table 6.4 Grade 4/3 students' categories of rocks

Students	Categories of rocks	Numbers of rocks
Group 1	1. rough rock	
	2. striped rock	
	3. shiny rock	
	4. smooth rock	
Group 2	1. pore rock	43, 18, 31
	2. smooth rock	37, 32
	4. striped rock	35, 33
	3. rough rock	17, 16, 34

After student presentations, Yanee led a discussion about classification of rocks based on scientific principles.

Yanee: "Did any groups has the same groups of rocks?"

Students: "No"

Yanee: "What is the correct way to group the rock? Do you know how the scientist group the rocks?"

Students: "There are igneous rocks, sedimentary rocks, and metamorphic rocks"

C. Revising the "Rock" Lesson

After Yanee's teaching the rock lesson, the Thamma School team including Yanee, Boon, and the researcher discussed the advantages and disadvantages of the practice the rocks lesson as follows.

1) Reflection on the Success of the Rock Lesson

Yanee and Boon reflected the good things of their rocks lesson and Yanee's teaching practice. They considering the following positive aspects of the lesson:

1.1) By focusing on questioning, they students expressed more enthusiasm. They responded with enthusiasm to questions such as "What the name of this rock?" "Could they float the water because of these pores?" "Why does it look like diamond?" Moreover, they found that students did a better job of presenting their findings to the class. However, there were some aspects of science process skills that students could not develop effectively. Students could plan, collect data, and analyze data, but they took long time for finishing their work. But Boon was satisfied with student's inquiry even it took too long time. He commented,

> I don't think we fell in time control. It is normal for students taking long time on what they are not familiar. Inquiry is new for them. We should let them touch, think, and exchange ideas. I think this activity (observation, and group the rock) is good. However, I will try to control the time in my next teaching (Boon's conversation during meeting after Yanee's teaching: 7 Feb, 07)

1.2) Focusing on students' understanding of the concept of rocks, Yanee expressed satisfaction and her belief of that students understood rocks. Yanee explained,

> I like this activity (observing and grouping the rocks.) At first, I thought it might be difficult for students. In contrast, my students could tell me the name and gave the explanation of the rocks quickly. I think that it is because they had experience on the rocks. They could see the pores on the rock. They touched and felt the smooth or rough on the rock surface. They could see the crystals making rock shiny." (Yanee's conversation during meeting after her teaching: 7 Feb, 07)

1.3) Focusing on teaching strategies, Yanee felt that she had improved in using a student centered approach. In the first lesson, she made conclusion for some of the groups. In the rock lesson, she let all students infer conclusions about rocks in their own words, and then later discussed the scientific definition.

1.4) Focusing on the goals of the modified lesson study, both teachers agreed that students were more enthusiast than the first lesson. They were more active in presenting their ideas in front of the class. They were working collaboratively in groups.

2) Reflection on What Could Be Improved in the Rock Lesson

Yanee, reflecting on the weak points of her teaching, noted that some students did not listen to the friends who presented ideas for the class. She suggested that a solution to use questions after each students' presentation to pool the students together to listen to friends. She explained,

> I noticed that some students did not listen to friend. I thought that I will ask question to the listeners. I should point the different points on the ideas of each group. Then I should ask them to clarify how it was different. (Yanee's conversation during meeting after her teaching: 7 Feb, 07)

Conclusion of Yanee's Practice of the "Rock" Lesson

Yanee's practice in the rock lesson showed that she incorporated many aspects of inquiry in this lesson. Her practice with inquiry was consistent with a student-centered approach. The activities enabled students to connect their prior knowledge of rocks to their investigation of rock samples which she brought. The students had opportunities to categorize the groups of rocks based on their criterions. Many of the students' initial knowledge about the groups of rock involved alternative conceptions. Therefore Yanee solved this problems by taking a role in leading them to understanding the scientist's explanation by asking students to read the book and discuss the concepts together with her. This practice was less student-centered approach in nature. Base on three observations of Yanee's teaching practices. There was improvement in Yanee's ability to use an inquiry approach. From the previous lesson, the team had asked Yanee to improve her teaching by waiting for students' answers and revealing students' important key words for their own conceptualize of earth science concept. She tried to followed the team's suggestion. She was impressed with how successful her students were in making explanations in their own words.

1.3.4 The "Soil" Lesson

A. Yanee's Teaching of the "Soil" Lesson

Yanee's teaching of the soil lesson was somewhat inquiry oriented as it contained some aspects of inquiry, but not all aspects of inquiry. The analysis was based on the science teacher inquiry rubric (NRC, 2000; and Beerer and Bodzin, 2004). The results are presented in Table 6.5.

Table 6.5 Brief of activities in the "soil" lesson with level of inquiry of Yanee's teaching in grade 4/3

5E's	Classroom practice	Level of inquiry
Engagement	1. Students identified the soil from the two bags containing two materials (one bag is sand, the other is soil) 2. Students gave opinion of what makes two materials different	4
Exploration	1. Students observed and described the characteristic of soils which they brought.	4
Explanation	1. Students presented the characteristic of their soils. 2. Students and teacher discussed the findings about soils and generated common understandings of the three groups of soils, following the scientific classification.	2
Extension	1. Students created a slogan for supporting soil conservation	Not observed
Evaluation	1. Students soil classification worksheet 2. Students working in groups 3. Students expressing opinion during discussion 4. Students evaluating their explanations	4

Table 6.5 indicates that Yanee conducted a high level of inquiry in some steps of the 5E inquiry cycle, especially in the engagement and exploration steps. In the engagement step, students were challenged to ask questions about soils. Next, students investigated the components of soils through their own observations. They wrote down details and drew picture of what they observed. Then students discussed their knowledge about the composition of soil and the type of soil in their own words (they had some prior knowledge of three types of soil: sand, clay, and loam.) However, some students did not know or conclude with a scientific explanation. Therefore, Yanee led them in a discussion of the three types of soil. In the extension step, initially, teacher expected students to create a slogan to tell about the disadvantages of destroying soil and invite people to preserve soil. This activity did not seem to link students' concept of soil to other situations. But it did support students in decision making about the use and value of soil. In every activity, students had opportunities to express their ideas and evaluate in other situations. Therefore, the evaluation of this lesson was conducted through formative assessment by the teacher and students' themselves.

B. Students in Grade 4/3 Learning on the "Soil" Lesson

The patterns of students learning were interpreted from classroom observations. These patterns showed the effectiveness of Yanee's teaching in to student learning about soil.

1) Students' Prior Knowledge of Soils

Yanee engaged students in learning about the soil topic by asking them to distinguish the difference between soils and sand. Students brainstormed and reacted to her question as follows.

Yanee: "How were soils and sand different?"
Student group 1: "Soil is more sticky than sand"
Student group2: "Soil is accumulated with many grains, but sand is separated grains"

Student group 3: “Soil is soft, but sand is hard”
Student group 4: “Sand is small grain”

Later, when Yanee asked “What makes the soils and sand different?” The students could not explain the factors that made them different. Therefore she used a more guided question.

Yanee: “Let’s grasp the soils and sand.. what’s happen?”
Naree: “Soil were shaped, but sand was separated grains”
Yanee: “That’s because of the adherence between soil grains”

2) Students Did Not Understand the Word “Classify”

After students investigated their soil, Yanee led students in a discussion of grouping soils based on scientific concepts.

Yanee: “What did you found in soil?”
Students: “Pieces of grass root, sand, rocks, date leaves and seeds”
Yanee: “How many group you could classify these things found in soil?”
Students were quiet.

When students were quiet, Yanee explained that classifying is the same as grouping things. She explained that they could classify things they found in soils into organism and non-organism. From this lesson, students constructed the components of soils, but they did not know about groups of soils. Yanee asked them to read in the book to further their understanding of groups of soil.

C. Revising the “Soil” Lesson

The Thamma School team including Yanee, Boon, and the researcher discussed the advantages and disadvantages of practice in the rock lesson after Yanee's teaching. The advantages and disadvantages of the soil lesson were as follows.

1) Reflection on the Success of the Soil Lesson

Yanee reflected that activities in the engagement step were simple and effective in explicating students' prior knowledge about soils.

2) Reflection on What Could Be Improved in the Soil Lesson

2.1) Students Could Classify, But Were Unfamiliar with the Term "Classify"

According to previous lessons, students were familiar with hands-on classification. But Yanee always used easy word like "grouping" when she wanted students to classify objects. In this activity she put the word "classify" on the worksheet. Many students raised hands and asked "what does it mean to classify the soils?" Therefore she had to explain and took more time to conduct the soil lesson.

2.2) Students Had Less Enthusiasm Because There Were Not Enough Learning Materials

In this lesson, the team planned to ask students to bring their own soils to class. Yanee forgot to tell the students to bring soils. Therefore she let the students get the soil from somewhere on the school grounds. Thus, the soil samples were not very different. Boon gave the following suggestion

> Students were not much enthusiasm because there was not enough soil samples for all students to observe. Next time, I will not forget to tell students or I should prepare some spare of soil samples (Pa's conversation during meeting after Yanee's teaching: 14 Feb, 07)

1.3) Alternative Ways to Help Students' Investigation on Components of Soils

Boon thought about using water in the investigation. He might prepare some water to the class as an alternative to magnifying lens for students. Boon realized that the water could help students see the light weight components of soils such as organism detritus.

Conclusion of Yanee's Practice of the "Soil" Lesson

Yanee's practice in the "soil" lesson contained some aspects of student-centered instruction. Students were curios about soils. They connected their assumptions about soils with their investigation to crate their own explanations of soils and it's components. One of the problems that made this lesson less effective was that Yanee forgot to ask students to prepare soil samples. In addition, her use of the technical word "classify" was confusing to students. Furthermore, Yanee did not have enough time for elaborating student knowledge.

Conclusion of Yanee's Practice

The evidence from Yanee's practices in three lesson plans supported the assumption that Yanee could translate her understanding of inquiry to practice by engaging students' curiosity with questions on what they learned, using collaborative work and small group discussion, concentrating on students prior knowledge and alternative conceptions, using hands-on activities, and using a variety of assessment tools in each step of the 5E instructional model. According to her practices in the three lessons, Yanee showed development in inquiry teaching gradually from the first lesson to the last lesson. Two things that enhanced her development with respect to inquiry were her translating of narrative understanding of inquiry into practice and the reflection on practice between herself and peers.

1.4 Yanee's Understanding of Inquiry after Lesson Study: Student-Centered Approach

The evidence from narratives after professional development focusing on the second metaphor and classroom case writing revealed that Yanee had improved in the narrative understanding of inquiry in following topics.

1.4.1 Yanee's Narrative Knowledge Constructed after Professional Development

After practicing all three lessons in the "mystery of the earth's crust" unit, Yanee wrote a second metaphor and a classroom case to reflect change in her practice. Yanee constructed a new metaphor "teacher as a rudder for life" and wrote hew experience of inquiry teaching in the classroom case entitled "Attractive by instructional media" The following narratives are Yanee's reflections on her practice.

A. Yanee's Second Metaphor

"Teacher as a Rudder for Life"

> Teacher is a profession which devoting both of effort and inner strength for teaching students to be good, competent, and happy. Teacher will be happy, if students could be success in their life. Teacher is a rudder for life, because teacher has to take care students in many aspects such as knowledge and behavior. When students have misunderstanding or alternative conception, teacher will help students to have a correct concept. When students have misbehavior, teacher will tell and change it. This is like a rudder which change direction for boat. Even there is strong storm, the boat could float and go to the goal by safety. (Yanee's second metaphor: March, 2007)

Yanee's second metaphor "teacher as a rudder of life" could be interpreted in relation to her development of narrative knowledge as follows.

1) Teaching Is Hard, But Has Great Value Because It Supports Students in Becoming Successful (Knowledge of Self)

Yanee realized the value of teacher profession as described in the second paragraph of her metaphor “teacher as a rudder for life.”

2) Teacher as the Helper for Students’ Conceptual Change (Knowledge of Instruction)

According to Yanee’s second metaphor, she realized teachers’ role in facilitating students to learn by themselves. In Yanee’s first metaphor “teacher as a magician”, She mentioned that the teacher was the person who translated knowledge for students, which was an example of teacher-centered teaching. In her second metaphor, she changed her role to be the facilitator for students, assisting them in constructing knowledge. She was still the “teller” for students when it came to classroom management and behavior..

B. Yanee’s Classroom Case

“Attractive by Instructional Media”

> In science period, students were enthusiastic in science learning. They were excited with many things on teacher’s table. Behind the classroom, I put many stuffs for earth science teaching. I prepared rock collection box, magnified lens, global model, map, soils, and so on. When science class started, students were paying big attention on what they will learn and when they will try these instructional medias. I used 5E inquiry lessons. I designed many activities. Students were enjoy participating. Some students asked questions, some discussed on my questions. It seems they were happy to try new experience and enjoy their learning. (Yanee’s classroom case writing: March, 2007)

1) Using Instructional Media to Interest Students (Knowledge of Instruction)

Yanee mentioned that instructional media impacted students enthusiasm for science investigations.

2) Students' Enthusiastic Supporting Students' Using Science Process Skills (Knowledge of Instruction)

Yanee realized that she felt that enthusiasm is important to successfully engage students in using science process skills. If students felt thirsty to know, they would find ways to learn. Therefore, Yanee felt that teachers should focus on enthusiasm, and what is happening inside students. In this way, science learning would be fun and valuable to them.

C. Things that Yanee Learned through Her Practice in Lesson Study

The following evidence illustrates the understanding of inquiry which Yanee developed during the process of the modified lesson study. Her understanding of inquiry could be identified in knowledge of instruction, knowledge of subject matter, knowledge of curriculum, knowledge of milieu, and knowledge of self.

1) Lessons Were Designed Effectively to Enhance Student Learning (Knowledge of Instruction)

Yanee designed and implemented inquiry teaching by using the 5E model. She reflected on her practice and felt that her teaching was inquiry because it enhanced students knowledge constructions, supported science process skills, and fostered the development of a scientific mind focusing on enthusiasm and enjoy in activity.

> I feel that my lessons was fit the 5E concepts and consistent for the students about knowledge, science process skill, enthusiasm, and their enjoy during working. (Yanee's journal: March, 2007)

2) Lesson Designing on Inquiry Way to Support Teacher Learning of Science Content (Knowledge of Subject Matter)

Yanee mentioned in her journal entries that she learned more earth science concepts that were useful in preparing her own lessons. She studied contents that were important for students, including components of earth's crust, categories of rocks, formation of rocks, components of soils, categories of soils, and conservation of the earth materials. Moreover, she studied some additional contents such as earthquakes, volcanoes, and tsunamis.

3) Learning Experience Should Reflect Core Curriculum and Students (Knowledge of Curriculum)

Yanee mentioned that she improved her knowledge of curriculum by designing her own lesson plans. She felt that it was important to focus students' learning on the expected outcomes which she included in the lesson plans.

> I evaluated students learning according to the expected outcomes which designed in the lessons. To design expected outcomes, I concerned on contents which students should know, the learning product which enhance their science process skills, and their enjoy on the work. (Yanee's journal: March, 2007)

4) Collaborative Work Is Valuable for Deeper Insight of Effective Teaching (Knowledge of Milieu)

Yanee thought that collaborative work on the modified lesson study was beneficial for improving inquiry teaching. Peers' reflection on her ideas or practices was valuable for creating direct improvement in student learning outcomes. Moreover, valued learning about new teaching techniques and activities

5) Confidence in Using 5E Inquiry (Knowledge of Self)

Yanee felt confident with the inquiry approach after her practice. She felt that science process skills and student discussion were effective ways to support students learning science through inquiry. She also mentioned that she would keep using the 5E instructional model for teaching science the next semester.

> I have confident on inquiry teaching. I think that it provided the opportunity for students to learn science, because students used science process skills which consisted in each step of 5E. Moreover, the students discussion would help them to share ideas for their knowledge. (Yanee's journal: March, 2007)

Conclusion of Yanee's Understanding of Inquiry after the Lesson Study

Yanee's reflection on her roles in science teaching in both the second metaphors and classroom case writing were very general. Her knowledge of self as reflected in her narratives showed that she was a teacher who was gentle and concerned with making students' happy and successful in constructing their own knowledge. The information from both metaphors revealed growth in knowledge of instruction. In the first metaphor, she focused on teacher-centered approaches which the teacher had to transfer knowledge to students. In the second metaphor, she mentioned her role in helping students develop conceptual change. From her classroom case writing, it was apparent that Yanee was becoming more a student-centered teaching. She used many activities and media. She activated students to question and discuss ideas. This was the way she helped her students construct knowledge or conceptual change. Moreover, after trying 5E inquiry lessons, she noticed that students were enthusiastic and this was of value in engaging students to use their ability to learn by inquiry.

1.5 Yanee's Growth after Participating in the Professional Development Model

Yanee fully participated in this professional development experience consisting of the workshop and the modified lesson study. Evidence of Yanee's learning and practice with respect to inquiry teaching while participating in this professional development revealed some aspects of professional growth. These aspects were curriculum, instruction, subject matter and self. Yanee's growth was reflected in her understanding of inquiry, translating of knowledge into practice, and reflecting for evaluate and improve her teaching. The patterns of Yanee's growth are discussed below.

1.5.1 Yanee Constructed an Understanding of the 5E Model of Inquiry, Applied to Earth Science through an Analytic Worksheet

Evidence from 5E earth science analytic worksheets indicated that Yanee developed an understanding of inquiry which corresponded to student-centered approaches. She could describe the aspects of inquiry in each step of the 5E inquiry model. She also understood the teacher's role in supporting students' learning science through inquiry.

1.5.2 Yanee Constructed an Understanding of Inquiry from Reflecting on Narrative Tools

The narrative tools that enhanced Yanee's construction of knowledge about teaching of this study were written cases reaction and classroom case writing. Reflection on written cases was an important process for enhancing Yanee constructed narrative knowledge of inquiry, particularly involving using small group discussion, scaffolding students' conception from alternative concept, using students descriptions of how to work, and moderating students' discussions. After she practiced inquiry teaching in her actual classroom, she reflected on her own experience though classroom case writing. The narrative knowledge reflected after practicing in the actual classroom was centered on students' excitement with instructional media leading to motivation and supporting students' use of science process skills.

1.5.3 Yanee Developed a More Student-Centered Teaching Approach by Translating Her Knowledge into Practice

Evidence from Yanee's practice in earth science teaching using 5E inquiry showed that she brought a new understanding of inquiry from the workshop into her practice in the actual classroom. She focused on aspects of inquiry in each step of her instruction, viewing students as the knowledge constructor. Her understanding of inquiry from direct experience of participating in 5E earth science instruction led her to emphasize curiosity and prior knowledge in the engagement step, linking students' prior knowledge to investigation, and providing students with opportunities to explain their own knowledge after investigations. She also incorporated knowledge which she constructed through narrative tools to support student-centered instruction, including the use of small group discussion, scaffolding students' conceptions from alternative conceptions, using students description of how to work as the assessment tool, and moderating students' discussion during each step of inquiry.

1.5.4 Yanee Changed Her View of Teaching to Be More Student-Centered in the Second Metaphor She Constructed after Practice

Yanee's second metaphor, "teacher as a rudder for life" clearly showed that Yanee changed her view of teaching to be more student-centered in nature. Her first metaphor, "teacher as a magician," centered on teaching as transferring knowledge to students. By contrast, her second metaphor illustrated that she viewed teaching as students' construction of their own knowledge. Yanee realized that this was hard work for teacher, but she realized that it would be useful for students to be successful on good, competent, and happy life.

1.5.5 Yanee Planned to Continue Inquiry Teaching with the 5E Instructional Model

Yanee reflected in her journal entries that the 5E instructional model was very effective for enhancing student learning of science focusing on content, science process skills, enthusiasm, and enjoyment of activities. She mentioned that she would use the 5E inquiry for science teaching in the future.

Conclusion of Yanee's Growth

Yanee's science teaching initially was teacher-centered in nature. She viewed that students as having low thinking abilities. Therefore, she felt that the learning experience should not too advanced beyond students' abilities. She followed textbooks for student learning in science. The teacher-centered philosophy was consistent with her first metaphor "teacher as a magician." She felt that students could not do many things by themselves. They needed teachers to take control and give them knowledge.

While participating in the processional development experience, Yanee developed an understanding of inquiry through direct experience with the 5E inquiry learning model in the three day workshop and reflection on written cases. The reflective process was beneficial in providing the opportunity to think about inquiry dilemmas and alternative solutions. She constructed many aspects of inquiry, for example, an understanding of how to engage students' curiosity and questions, use collaborative work, use small group discussion, focus on students' prior knowledge and alternative conceptions, use hands-on activities, and use a variety of assessment tools. Evidence from practice in her actual classroom showed that these aspects of inquiry which she inferred were applied as a new practice. Significant aspects of the modified lesson study such as inquiry on lesson designing and collaborative work were important factors in helping Yanee implement inquiry in her actual classroom situation.

After applying knowledge of inquiry in her practice, Yanee demonstrated a change, not only in inquiry practice, but also with respect to her view of teaching. According to her second metaphor “teacher as a rudder for life” she no longer viewed that the teacher as a transferor of knowledge to students. She perceived a value in the teacher facilitating students’ construct knowledge by themselves.

2. Case 4: Mr. Boon

2.1 Boon’s Initial Understanding of Inquiry: Student-Center Approach

Boon’s interview and the first metaphor revealed that his pedagogy was student-centered approach emphasized on thinking and discussion with less hands-on activity. There was a problem on lack of science equipment of this school. Therefore Boon solved problem by using simple activity combined the learning steps of listening, thinking, questioning, and writing.

2.1.1 Boon’s Interview

The interview before workshop presented Boon’s philosophy in science. He viewed that students should learn by hands-on and construct their own knowledge. He mentioned that his school lacked of science equipment and no laboratory room. Therefore he had his own teaching style in follow.

A. Simple Activity with Students’ Explanation

Boon used the simple activities for enhancing students’ learning science. He did not rely on text book. These activities were simple experiment, observation, and students’ explanation on the specific topic.

> I prefer to prepare simple experiment for students. Students will tell answer. I will not tell the right answer, but I will asked all students to show their ideas and discuss whose is close to the scientific explanation. (Boon’s interview: July, 2006)

B. Teacher Waiting Time for Students' Answer

Boon thought that waiting time for students answer is important technique. During this time, students could organize their ideas which enhances the good answer.

> I use questions in my teaching. When I ask questions, I have to wait for their answers with patient. Moreover, I have to teach them to have thoughtful manner in speaking and listening. (Boon's interview: July, 2006)

C. Teacher Focusing on Listening, Thinking, Questioning, and Writing

Boon connected his belief of the Buddha's way of learning into his teaching practice. He adopted the steps of listening, thinking, questioning, and writing for enhancing student constructing of science knowledge.

> I think that learning could simple happen just we follow the Buddha's way of learning that is listening, thinking, questioning, and writing. It is also similar to the way of science learning which emphasizes observation, question, and data collection. (Boon's interview: July, 2006)

D. Teacher as Daddy Who Provides the Good Relationship with Students

Boon mentioned that good relationship between teacher and students is the important factor to enhance students learning. He viewed that the way of teaching similar to father governing the children with discipline, honest, and responsibility benefit for teacher direct students learning.

> My teaching has pattern as daddy and children. Students could be confident in teacher. It is important to build discipline, honest, and responsibility, therefore

children need the warm from daddy to follow which help daddy teaching easier. (Boon's interview: July, 2006)

2.1.2 Boon's Teaching Metaphor

The evidence from Boon's narratives of his teaching metaphor illustrated his narrative knowledge respectively to his view of teaching and his understanding of inquiry. The following metaphor is the description of Boon's view on student-centered teaching.

"Teacher as the Sun"

The sun is a big star which has given light to earth for long time. Earth has been changed for million years under the light from the sun. I metaphor that teacher as the sun, because the sun does it's role perfectly. Teacher also has a biggest role in this society. Teacher always helps and suggests to students. Moreover, teacher has to give love, warm, and understanding to all students. It's important role of teacher that he/she has to teach students to think, distinguish, compare, analyze, synthesize about what they have learn by observe, experiment to construct their own knowledge for using in daily life and extend to society. Knowledge is good, but sometimes there is dark knowledge. Teacher should teach students to know that knowledge has some good and bad dimensions. They should know and choose the good dimension for the quality life. I know that it is difficult to do it, but I think that teacher should complete this role just like the sun keeping doing it's role in long period. (Boon's the first metaphor: 11 Nov., 2006)

A. Students Think to Construct Their Own Knowledge (Knowledge of Students)

Boon viewed that teacher should not give knowledge to students. In contrast, teacher had to support students to construct knowledge by thinking skills (distinguishing, comparing, analyzing, and synthesizing). The thinking skills did not only help students constructing knowledge, but also it helped students applying knowledge in their lives.

B. Teacher Roles to Facilitate Students to Construct Knowledge (Knowledge of Instruction)

Boon role in teaching was centered on facilitating students learning with the friendly environment. His viewed of teacher helped students constructing knowledge and facilitating their learning with good feeling as environment was the best thing for students. His teaching relevant to the sun's role on the perfectly and huge responsibility.

C. Teaching Is Difficult, But It Is Value to Do (Knowledge of Self)

Boon viewed that thinking skills is beneficial for students decision making. However, it was not easy to develop students' thinking skills. It took time on students practicing with teacher's devotion.

Conclusion of Boon's Initial Understanding of Inquiry

Boon's view of instruction was concerned on students construction of knowledge. Because of lacking learning media in the school, he used less centered on hands-on activities which disadvantage for supporting students to use science process skill. The metaphor "teacher as the sun" revealed Boon's view of teaching consistent with the teacher's role and intention for students-centered learning. He focused thinking skills as the important tool to help students constructing their own knowledge. Teacher's role was centered on preparing good environment for student readiness. He focused on facilitating the students' feeling of friendly and discipline.

2.2 Boon's Learning during the Workshop

Boon's data from field notes, worksheets, and journal entries illustrated that Boon developed earth science content and the understanding of inquiry. The following topics describes Boon's learning during workshop.

2.2.1 Boon's Learning through 5E Earth Science Instruction during the Workshop

Boon reflected on the journal entries after 5E earth science instruction about his science concepts learning. He mentioned that he learned many contents of earth science. These earth science contents were the groups of rocks, characteristic of rocks, the sources of rocks, classification of rocks, cloud formation, types of cloud, and the process of erosion and weathering. The following patterns were discussed on Boon's learning in inquiry lessons

A. Boon Developed Science Contents through 5E Earth Science Instruction: The Leader of Discussion

Boon had outstanding character of the leader who lead the discussion for the class. He gave long conversation with some challenges for others to discuss on his ideas. The following is example of Boon's constructing knowledge of earth science content through discussion after hands-on activities.

On the 5E rock instruction, the researcher challenged teachers to think about characteristic of rocks with the unseen rock "Pumice" which is light and contains with lots of holes. The researcher put the rock in the cup of water. Participants were surprise that this rock could float on water.

Keaw: "How did it float?"
Researcher: "Why could this rock float?"
Nida: "It's light-weight"
Researcher: "Anybody has any idea?"

Boon: “Maybe it contains air inside, because there are many holes on the rock”

After the experiment on the 5E weathering instruction, researcher and participants discussed on the results of experiment. Participants noticed the different between 2 boxes after experiment. Boon was the first person who answered the researcher’s question and discussed for weathering concept.

Researcher: “Why are there some cracks on plaster cement of the blue box?”

Boon: “Because water has more pressure than air… the water balloon in blue box is expended from water pressure”

Keaw: “The water from balloon is out from balloon and penetrates along the plaster cement”

Researcher: “Can you tell me what are factors make the plaster crack… water, air, or animal?”

Boon: “I don’t think it is from water or air… I think it is about force”

Researcher: “Yes… This is a good example of force breaking rock”

Researcher: “Have you ever seen what happen in the glacier?”

Pim: “Yes. The ice could break rock. Normally, there is some water inside the rock or the under the ground. When the snow fall, water inside the rock will be frozen as ice. The ice is expand volume and it could break the rock.”

Researcher: “Yes. Cloud you give more phenomena that you have ever seen?”

Boon: “Water which is accumulate long time inside the crack of road also cloud brake the road”

2.2.2 Boon Developed Inquiry Content through 5E Earth Science Instruction

Boon’s journal entries revealed the understanding of inquiry which he got from reflecting on his learning on 5E earth science instruction. He explained the importance of hands-on activities on exploration. He mentioned on small group discussion and brainstorming in students group work. He considered of teacher's role to facilitate student discussion for consolidating their knowledge. He also noted that learning resource and games were important to engage students to learn in specific topic. His journal expressed the inquiry content as follows.

> I think this activity (rock instruction) is good showing the steps of inquiry. I would allow students to touch, observe and experiment. Then students could synthesize their inquiry. They might feel fun for joining, brainstorming, exchanging idea and making conclusion together. Moreover, the learning resource such as games would help student learning better. I think that student discussion is important, but teacher should join their discussion for students' more understanding. (Boon's journal of 5E rock instruction: 11 Nov., 06)

2.2.3 Boon's Narrative Knowledge through Case-Based Pedagogy

Boon reflected on two written cases "Too many questions, too little time" and "Between a rock and a hard place: Assessment dilemmas in inquiry science." His reflection revealed the understanding of inquiry in many aspects. The following description presents of Boon's learning through case-based pedagogy.

A. Small Group Discussion Strategy for Students Exchanging Ideas

Boon reflected that using small group discussion enhanced students learning. Some students were shy or quiet. Teacher could use small group discussion before bringing students to the class discussion. According to his ideas, Small group discussion would be effective if students exchange ideas and respect to friends' idea.

B. Teacher Facilitating Students' Collaborative Work

Boon reflected on the second written case that "…The problem was that students weren't sure on their ideas… right or wrong. Then teacher in this case should help students to support their answer." Based on his words, Boon solved the problem by using group collaborative work which students could share ideas for their confidence. Teacher should make sure on the topics and distribute to student group. Teacher should prove students understanding by asking them to present ideas during and after working.

C. Students Respecting on Each Other's Ideas

Boon viewed that one important factor helping students constructing knowledge was collaborative work with the respecting on each other.

> According to the case, it seemed that students were familiar not to response on teacher's question. I think the students in this case need to learn to respect to each other. (Boon's the first case reflection: 11 Nov., 06)

D. Assess on Product and Process to Make Sure of Students Learn

Boon reflected on the case which was presenting his knowledge in assessment. He thought that teacher should have opportunity to assess for both students' product and process of their work to make sure that students were understanding on their hands-on.

> I think that the teacher in this case should have more assessment (more than checklist) For example, she should ask the students how to get their product or ask them to present their product to the class. This way will help teacher know how students learn. (Boon's the second case reflection: 11 Nov., 06)

E. Make Clear for Objectives of Students' Work and Make Sure that Students Know

Boon reflected to the second written case that students' copy work might result from misunderstanding on teacher. He gave suggestion that teacher should make clear for objectives of students' work and make sure they know what to do.

> I think teacher in this case was not clear about her direction. She was not clear on what she wanted to assess. Then her students also were not clear on what they did…she checked her students whether they put the rocks in the right position (rock classification). I think that just putting rock cannot assess students' understanding on properties of rocks. Maybe students just put the rocks without any reasons, because teacher didn't tell student on the objectives of their work. (Boon's the second case reflection: 11 Nov., 06)

Conclusion of Boon's Understanding of Inquiry During the Workshop

Boon developed understanding in both earth science contents and inquiry from the workshop. He learned earth science contents from participating in 5E inquiry experience. He had opportunity to construct his own knowledge with hands-on activity and communicating the ideas with peers. Throughout his direct experience on the inquiry learning, he reflected the understanding of inquiry aspects. Theses aspects consisted of direct sensing on things, interpreting on those senses, communicating ideas for the common conclusion. The role of teacher was focusing on facilitate in students conversation and discussion. The evidence of Boon's reflection on two written cases revealed that he solved the problem on the written cases by using the inquiry focusing student-centered approach. From the initial interview, his view of setting students learning was focusing on student-centered approach which students were expected to present ideas to teacher. After reflecting to written cases, he realized on students' collaborative working and discussing to enhance their learning. The students' role was express ideas with the respect on each other. The teacher's roles were facilitating students by making clear on objectives for working and assessing them on learning product and process.

2.3 Boon's Classroom Practice: More Inquiry in Science Process Skills

Boon was the advisor of grade 4/1. He had the responsibility to teach many subjects including science subject for his classroom. Thirty five Students sat in the fixed group. They sit on the floor and small table. Boon told that it was the effective way for students moving in the group work. There were seven groups with five students. The students in groups were mixed gender. The advisor's table was settled in front of the classroom. During the modified lesson study, Boon had implemented three lessons of the earth's crust, rocks, and soils as re-teaching for the revised lessons from Yanee's teaching.

Boon's practice on using 5E instructional model consisted of lesson planning, re-teaching, and revising lesson. The student learning was described to see the effectiveness of his teaching practice. Boon's development of teaching was also found from the evidence of discussion, journal writing, and interview during participating in the modified lesson study.

2.3.1 The "Earth's Crust" Lesson

Boon's practice in the modified lesson study was sought for the patterns of inquiry relevant to his narrative knowledge. Moreover, the findings of student learning in his teaching were clarified to see the effectiveness of his classroom practice. After revising of the lessons in Yanee's teaching practices. Boon took responsibility to re-teaching in order to consolidate students' inquiry learning. His re-teaching was described below.

A. Boon's Re-teaching of the "Earth's Crust" Lesson

Boon's practice was compared to the science teacher inquiry rubric (NRC, 2000: and Beerer and Bodzin, 2004) in order to see the level of inquiry. The findings presented that Boon's re-teaching on "earth crust" topic was somewhat student-centered teaching which contained highest and high level of inquiry as same as finding in Yanee's previous teaching (Table 6.6).

Table 6.6 Brief of activities in the "earth's crust" lesson with level of inquiry of Boon's re-teaching in grade 4/1

5E's	Classroom practice	Level of inquiry
Engagement	1. Students observed and presented what they knew or what to know from the earth model and map	4
Exploration	1. Students explored the earth crust on the school and brought their interested things, rocks, or soils to the class 2. Students recorded what they observed and classify their interested things into group of "organism" or "non-organism"	3
Explanation	1. Students presented the group findings of the area that they observed and the classification of their interested things 2. Students and teacher discussed the common understanding of the school area (flood plain)	3
Extension	1. Students matched the scenery of earth crust pictures with their names.* 2. Students and teacher discussed for others earth crust found in other regions (such as mountain, desert, grass plain, valley, glacier and so on)	4
Evaluation	1. Students creating the book "My Earth" from the paper which was cut and put in different level to see dimension of each scenery of earth crust 2. Student working in group and worksheet 3. Student expressing opinion during discussion 4. Student evaluating their explanation	4

Remark: * revising activities from Yanee's teaching

In the engagement and the exploration steps, Boon kept the same activities, except the engagement, exploration, and elaboration which had some revision of activities. In the engagement and the exploration steps, the things revised in his re-teaching was about teacher making sure on what students would do in the activities and what they had learned. He always asked the students to tell him what they planed, expected, and understand. This strategy helped students to be mind's-on what they were doing and what made sense to them. In the elaboration step, Boon brought matching pictures game to the class. Students matched the scenery of earth crust pictures with names. It helped students to recognized of many scenery of earth crust.

B. Students in Grade 4/1 Learning on the "Earth's Crust" Lesson

The finings of re-teaching in grade 4/1 were similar of grade 4/3 students learning. Some different things that Boon could improve the ways to conduct students constructed their own knowledge about the school's area by themselves. Students recorded their investigation more systematic which helped them to make connection on things they found around the school. Table 6.7 is the example of students data collection.

Table 6.7 Grade 4/1 Students' conception of the "earth crust" topic

Things to observe	Student group 1	Student group 3
Characteristic of area	Land, football field, plain	Football field, Land
Organism	Ant, fly, caterpillar	Ant, Ladybug, Spider
Non-organism	Rock, leave*, tree*	Rock, cement floor, dead leave
Differences between organism and non-organism	Organism can eat and breath, but non-organism cannot	Organism can grow, breath, and walk, but non-organism cannot
The relationship among the area, organism, and non-organism	Organism can take benefit from the area, but non-organism cannot take any benefit from it	When the organism die, it will be fertilizer on the land. The tree will take up them as the food and grow up.

Remark: * alternative conception

After that, Boon and students discussed about the relationship among the area, organism, and non-organism. Then he brought the new activity to students. This activity was revised for enhancing students to have more familiar with other scenery of the earth crust. Students were enjoy playing the matching game between the picture of scenery and it's name. Finally, students created the earth book with some ideas of the different scenery of earth crust.

2.3.2 The "Rock" Lesson

A. Boon's Re-teaching of the "Rock" Lesson

The findings of Boon' practice based on the science teacher inquiry rubric (NRC, 2000; Beerer and Bodzin, 2004) showed that Boon's re-teaching on the "rock" lesson was somewhat student-centered teaching (Table 6.8) which contained highest and high level of inquiry as same as finding in Yanee's previous teaching.

Table 6.8 Brief of activities in the "rock" lesson with level of inquiry of Boon's re-teaching in grade 4/1

5E's	Classroom practice	Level of inquiry
Engagement	1. Students explained prior knowledge through activities choosing rocks from the hard things with defining of "rock" in their opinion.	4
Exploration	1. Students observed and drew the rocks which they collected in the school. 2. Students in each group classified rocks which teacher prepared from the rock box.	4
Explanation	1. Students presented and concluded the group of rocks from their investigation.* 2. Students discussed on the findings of rock classification 3. Students read book and made common understanding on	4

Table 6.8 (Continued)

5E's	Classroom practice	Level of inquiry
	the three groups of rock following the scientist classification.	
Extension	1. Teacher demonstrated the experiment on the formation of the rocks. The experiment was showed how the crayon (representing rock) changed by heat and compaction. 2. Students discussed what they noticed from the experiment with the key words 1) the rock group 1: cooling from lava which spread out along the 2) the rock group 2: under high pressure and temperature for transforming 3) the rock group 3: sediments piling up and compacted under pressure	2
Evaluation	1. Student creating the model of rock formation 2. Students' rock classification worksheet 3. Student working in group 4. Student expressing opinion during discussion 5. Student evaluating their explanation	4

Remark: * revising activities from Yanee's teaching

Boon conducted the rock lesson with same activities. His re-teaching presented the higher level of inquiry compared to Yanee's teaching.

B. Students in Grade 4/1 Learning on the "Rock" Lesson

1) Students' Prior Knowledge of Rocks: Misunderstanding between Rocks and Cement

In engagement step, Boon challenged students with unknown objects. There were three objects which were rock (Andesite), mineral

(Calcite) and big piece of cement. Students thought that cement is rock. The following conversations were the students' prior knowledge of rocks.

Boon: "What object is rock?"

Student A picked a big piece of cement: "This is a limestone"

Boon: "How did you know it is a limestone?"

Student A: "It made from shells of sea animal"

Boon "This is not rock. I just pick from the under constructed building. It made from combination of cement, water, sand, and rocks"

2) Students' Curios about Floating Rocks

Students were curious on the characteristic of Pumice which contains many pores and has the light weigh. They wondered that it looked like sponge. Thus it might be float.

Group 3: "This rock is very light. It could float"

Boon: "Did you test that it can float?"

Group 3: "Not yet, but I think that it is very light and contains many pores likes sponge"

Boon: "Let's test on what you are curios?"

3) Students' Categories of Rocks

In exploration step, Boon let the students observed the nine rock samples with the two general criterions providing that were color and grain. Students noted what they observed and created their own categories of rocks. Table 6.9 and excerpt of students and Boon are the examples of the categories of rock from students' investigation.

Table 6.9 Grade 4/1 students' categories of rocks

Students	Categories of rock	Number of rock
Group 3	1. Igneous rock	35
	2. Sedimentary rock	34
	3. Metamorphic rock	28
Group 4	1. Sand rock	33
	2. Sedimentary rock	34
	3. Igneous rock	32
	4. Marble	11
Group 2	1. Igneous rock	35
	2. Sand rock	40
	3. Metamorphic rock	28

After student presentations, Boon asked students to read the book for searching the information of classification of rock

Boon: "How many groups of rock according to the book?"

Students: "There are three groups of rocks that are igneous, sedimentary, and metamorphic rock"

Boon: "From your investigation, you showed the explanation close to the book. You did the good job."

4) Students' Conceptualization in Rock Formation Concept

In elaboration step, Boon demonstrated the experiment on rock formation. He asked students for their understanding on the experiment. He prepared the small pieces of crayon and put them in the aluminum foil bag. Then he hit the bag and showed what happened to the crayon inside the bag. After that he heat the bag and showed what inside the bag. Finally he let the bag cooling down and showed what inside the bag. His demonstration represented the process of rock formation which happened repeatable and become "rock cycle"

Boon: "What's type of rocks which these small pieces of crayon in the bag represent?"

Students: "Sedimentary rock"

Boon: "When I hit the bag, there is a change to the rock inside the bag. Can you tell me what kind of rock in side the bag?"

Students: "Metamorphic rock"

Boon: "Right. It's changed because of depression"

Boon: "Are there any change when the bag get some heat?"

Students: "The crayon is melt."

Boon: "This melt crayon is representing by lava. What kind of rock form by cooling lava?"

Students: "Igneous rock"

2.3.3 The "Soil" Lesson

A. Boon's Re-teaching on the "Soil" Lesson

The findings of Boon's re-teaching on the soil lesson was somewhat student-centered teaching presented in Table 6.10. Based on the science teacher inquiry rubric, (NRC, 2000; Beerer and Bodzin, 2004) his practice contained highest and high level of inquiry which similar to Yanee's previous teaching.

Boon had learned things to improve in this lesson from observing Yanee's teaching practice. In Yanee's class, students did not pay much enthusiasm because they did not have enough soil samples for every students investigating. Therefore, Boon asked students to get their own soil samples and he also prepare some.

Other interesting teaching that Boon noticed from Yanee's students. Some of students wondered about using water for soil investigation. Therefore he prepared water in his class in case that some students wondered to use water in the study of soils.

Table 6.10 Brief of activities in the "soil" lesson with level of inquiry of Boon's re-teaching in grade 4/1

5E's	Classroom practice	Level of inquiry
Engagement	1. Students identified the soils from the two bags containing the mystery materials (one bag is sand, the other is soils) 2. Students gave opinion of what makes difference of materials	4
Exploration	1. Boon asked students read the worksheet and made sure that students understand the word "classify"* 2. Students investigated their soil with magnified lens and water.* 3. Students described the characteristic of the soil which they brought.	4
Explanation	1. Students presented the characteristic of their soil. 2. Students discussed the findings of soil 3. Students read book and make common understanding on the three groups of soil following the scientist classification	4
Extension	1. Students created the slogan for supporting soil conservation	Not observed
Evaluation	1. Students' soil classification worksheet 2. Student working in group 3. Student expressing opinion during discussion 4. Student evaluating their explanation	4

Remark: * revising activities from Yanee's teaching

Conclusion of Boon's Practice

Boon's practices in three lesson plans revealed his understanding of inquiry similar to Yanee. He translated his understanding of inquiry to practice by engaging students' curiosity with questions on what they learned, using collaborative work and small group discussion, concentrating on students prior knowledge and alternative conceptions, using hands-on activities, and using a variety of assessment tools in each step of the 5E instructional model. Boon's practice in re-teaching revealed that he implemented the lessons in the same level of inquiry found in Yanee's teaching. However, Boon's practice had more effectiveness in the sense of most of students' participation with more concentrating, and discipline. The revising lesson plan after Yanee's teaching was the guidance for Boon improving his practice to be effectiveness in terms of classroom management and endeavor to engage students in their own inquiry consisting of curiosity, investigation, and explanation.

2.4 Boon's Understanding of Inquiry after Lesson Study

Boon's understanding of inquiry after lesson study was found in his narratives. The second teaching metaphor was "teacher as a mirror" and classroom case was "What is Matter?" His narratives revealed that he reflected the understanding which presented many aspects of student-centered teaching.

2.4.1 Boon's Second Metaphor

"Teacher as a Mirror"

> Mirror doesn't have light in itself. It needs light to reflect and make itself being bright. Students could be interesting on themselves if they see from the mirror. I think that students are looking themselves from mirror as same as they are learning through 5E inquiry learning. During learning, teacher acted as a mirror to help reflect students. In engagement step, students will be interesting on themselves. In the exploration step, students will explore themselves. After that, they could explain and conclude about something good or bad. Then they will improve the bad thing and elaborate the good thing. At last, they will evaluate their own value.
>
> I belief that it depends on teacher whether students will love science. Teacher has role to encourage student to be interested on inquiry. Teacher science characteristic is also important to help student belief in science and

belief in the reason. Moreover, instructional media, science activity, teaching technique are crucial for science learning.

The mirror is not only reflecting to students learning, but also reflecting to teacher teaching quality his/her self. I thought that the result of how students learned is the good image to reflect how good teacher teach. Therefore teacher should often be interested, explore, explain, elaborate, and evaluation how to teach at the same time during reflecting to how students learn.

I would improve my students on their learning, discipline, merit, and awareness in themselves. They should belief in reasoning. They should see and understand that anything is born by itself. They will not accuse or blame others about their own mistake. (Boon's second metaphor: March, 2007)

According to Boon's second metaphor, he reflected his new role for inquiry teaching. He realized on the teacher as a facilitator on the sense of reflection which could support his students to construct their own knowledge from their practice (learning process and product). The narrative knowledge hidden in the "teacher as a mirror" was interpreted as follows.

A. Reflection Enhancing Students Evaluate Themselves in Whole Process of Learning (Knowledge of Instruction)

Boon used reflection to support students in their inquiry. Reflective process should occur from the beginning until the end of the lesson

During learning, teacher acted as a mirror to help reflect students. In engagement step, students will be interesting on themselves. In the exploration step, students will explore themselves. After that, they could explain and conclude about something good or bad. Then they will improve the bad thing and elaborate the good thing. At last, they will evaluate their own value. (Part of Boon's second metaphor: March, 2007)

B. Reflection Enhancing Teacher Evaluate Himself for Improving Teaching (Knowledge of Self)

Boon's view that the best evidence to evaluate the effectiveness of teacher's teaching was reflected from students learning. It was important for teacher to notice student learning process from the beginning of the lesson. He thought that teaching was the inquiry process similarly to 5E inquiry for creating the effective teaching for students.

> The mirror is not only reflecting to students learning, but also reflecting to teacher teaching quality his/her self. I thought that the result of how students learned is the good image to reflect how good teacher teach. Therefore teacher should often be interested, explore, explain, elaborate, and evaluation how to teach at the same time during reflecting to how students learn. (Part of Boon's second metaphor: March, 2007)

C. Teacher as an Inspiration for Students Loving Science (Knowledge of Self)

Boon believed that students' feeling love science was depended on teacher. It was important for teacher to develop scientific character.

> I believe that it depends on teacher whether students will love science. Teacher has role to encourage student to be interested on inquiry. Teacher science characteristic is also important to help student belief in science and belief in the reason. (Part of Boon's second metaphor: March, 2007)

2.4.2 Boon's Classroom Case Writing

Boon classroom case writing was a story of one teacher who wanted to improve students' learning outcome on science subject. He told the process of his work on this problem. He chose 5E instructional model to enhance students science leaning. The following classroom case was written by Boon.

“What is Matter?”

Somchai is a grade 4 elementary teacher. His class has 40 students. He teaches for all subject for his classroom, because the school lacks many teachers. The students are 22 girls and 18 boys. There are 12 good, 15 medium, 8 normal, and 5 low in learning ability. Somchai has to know the difference of students in learning ability, behavior, and their family or status.

At the end of month, the principal have meeting with all teachers. This month, he complains that the learning achievement of grade 3 students in last year was very low, especially in science subject. He wanted teacher improve students’ learning situation.

Somchai come to meet Somsri, the teacher who taught grade 3 last year. Somchai asked Somsri to show him the students’ learning outcome. He also asked Somsri about his students’ situation when they were in grade 3. He made a record for planning science instruction for his students. He wanted his students love science. He had to think about teaching technique, activity and evaluation. Therefore he and his friend who teach in the same grade designed to work together for science instruction by using lesson study. They choose 5E inquiry teaching technique to help student learning science.

Somchai choose matter topic for research lesson. His classroom teaching were in following;

Somchai started the lesson by asking general questions such as day, students’ feeling, and the weather. After that, he engaged students to be enthusiasm and thirsty to inquiry on what they want to know.
He asked question “What do you see in our classroom?” and let students answer one by one. He continue question “Why do you know that table is table, chair is chair….?” Students told that “Because we can touch and see them”
Somchai: “Are there any thing else besides seeing and touching?”

Students: “They have weight, and need area”

Somchai: “Do you know the word of things that you can see, touch, weight, and give them area?”

Students were in quiet. However, there were 2 students tried to answer.

Booncherd and Sopita: “It is matter”

Somchai: “How do you know that is matter?”

Booncherd and Sopita: “It can touch, have weight, and need area”

Exploration phase, Somchai asked students to find out their matter. It could be anything that they think it is matter. He gave the worksheet to record in following

- “body” prove by………..
- “weight” prove by……….
- “need area” prove by………
- “touch” prove by………

Explanation phase, students were asked to present what they found and make the conclusion together.

Elaboration phase, Somchai asked students to analyze their material to find more characteristic of each material. Then asked students to record their material on the blackboard.

Evaluation phase, Somchai evaluated his students by observing students’ answering, participating in activity, worksheet recording.

From above story, students could learn science enjoying on their interesting. They used reasonable thinking during experience through their inquiry. Their confidence must be higher which will help their learning outcome improving.” (Boon’s classroom case writing: March, 2007)

Boon stimulated this story for reflected the overall of his learning through the professional development. The narrative knowledge was reflected as follows.

A. Boon's Insight of 5E Inquiry Teaching and Learning (Knowledge of Instruction)

The classroom case reflected Boon's understanding on how to set learning experience for students to be inquiry concerning on student-centered approach.

B. Boon's Belief of Inquiry (Knowledge of Self)

Boon presented his belief of inquiry as an effective learning approach for student in senses of fun, science process skills, thinking skills, and developing scientific character.

2.4.3 Things that Boon Learned through His Practice in Lesson Study

During participating in the modified lesson study, Boon reflected his learning, feeling, and impression about 5E inquiry through journal entries. The following excerpts revealed Boon's understanding of inquiry which relevant on narrative knowledge including, knowledge of instruction, knowledge of curriculum, knowledge of milieu, and knowledge of self.

A. Teacher as a Facilitator for Students' Reflection and Inquiry (Knowledge of Instruction)

Boon realized that the effective way for developing students learning in science should combine reflection and inquiry. Students could construct knowledge through hands-on focusing science process skills. Reflective thinking could support their inquiry because students rethink on what they know, what they don't know and what they want to know. Reflective thinking would help them to decision in their lives.

> In my instruction, students used science process skills in their hands-on activities. I also brought reflective thinking process to the instruction. I think reflection will help student to concentrate on their work. They rethink on what they don't know and what to know. It is important to bring what they know connected in their real lives. (Boon's journal: March, 2007)

B. Lesson Design Should Concern on Students and Teacher Reflecting after Teaching (Knowledge of Curriculum)

Boon designed lesson plan by studying on curriculum documents to see the relation between content and selected the appropriate learning outcomes for student. After determining the contents and outcomes, He designed the objectives, learning activities, learning media, and rubrics. He also that teacher should record teaching and suggestion after teaching.

C. Mixed Ability Collaborative Working (Knowledge of Student)

Boon set learning environment by collaborative learning. He preferred to set students group with mix ability. He thought that it would support students construct knowledge and confidence.

> I set the mix ability group for my students. In one group, it should have the high, medium, and low ability students. Students could learn together with happiness for sharing ideas. It is important for me to see the ability of each student. Working in group also support them to be confidence in themselves. (Boon's journal: March, 2007)

D. Inquiry Reflected the Nature of Science for Students (Knowledge of Subject Matter)

Boon thought that nature of students was easy lead them to the nature of science. Young students were active to curios. Teacher should know this point and lead them to develop their scientific methods.

> I think inquiry is relevant to nature of young students. They have curiosity. Teacher should effectively use the nature of young students leading them to develop science method. It is important for students to depend on the nature of science which belief that knowledge around us could be answered by seeking for reasoning. Science will support them to have. (Boon’s journal: March, 2007)

E. Effectiveness of the Lesson Study in Sustaining Teacher Development of Inquiry Lesson (Knowledge of Instruction)

Boon reflected on the effectiveness of the lesson study that it provided the opportunity in the authentic practice involving study about students, 5E inquiry, and science activity. Moreover, he could translate the knowledge from the workshop to develop students learning.

> I brought teaching techniques which I know from the workshop that were collaborative working, demonstration, experiment, and discussion into my real practice. The lesson study gave opportunity to bring knowledge in authentic. I designed, planned, and studied for implement inquiry in classroom. (Boon’s journal: March, 2007)

Conclusion of Boon’s Understanding of Inquiry after the Lesson Study

Boon’ s the second metaphor reflected the view consistent with student-centered and inquiry teaching when compared to his first metaphor the “teacher as the sun” The difference was centered on the aspect of inquiry that he emphasized. On the first metaphor, he focused thinking skills as the important tool to help students constructing their own knowledge. Teacher's role was centered on preparing good environment for student readiness in study. He focused on facilitating the students' feeling of friendly and discipline. The second metaphor provided the evidence of his extended vision on inquiry teaching in aspect of developing students to be reflective practitioner who could construct and evaluate by themselves. The process of Boon's learning and what he had learned effected to him which could see from the story of "Somchai" the teacher who believed in inquiry and student-centered approach for enhancing science learning. Base on this story, there was some narrative knowledge hidden in Boon's classroom case writing after participating in the whole professional development.

2.5 Boon's Growth after Participating in the Processional Development Model

2.5.1 Boon Constructed the Understanding of Inquiry from Reflecting on Learning of 5E Earth Science

The journal entries after learning of 5E earth science instruction reflected Boon's understanding of inquiry. He learned aspects of inquiry relevantly to student-centered approach.

2.5.2 Boon Constructed the Understanding of Inquiry from Reflecting on Narrative Tools

Based on written case reaction, Boon understood the inquiry from reflecting on narratives. He constructed his own narrative knowledge consistent with inquiry. These narrative knowledge were presented mostly in knowledge of instruction such as using small group discussion, facilitating students' collaborative work, supporting students to respect on each others, assess on students' product and process of learning, and making clear for objectives before let students work. After participating whole professional development, Boon constructed his own story in teaching. His story revealed knowledge of his learning which could describe his understanding of inquiry. His narrative knowledge on his classroom case writing consisted of knowledge of instruction and knowledge of self which presented that he belief in inquiry teaching to develop students better in science learning.

2.5.3 Boon Translated the Understanding of Inquiry into Practice

From the initial of professional development, Boon had the student-centered view of inquiry already, but did not focus on science process skills. The evidence of learning in three day workshop, and the modified lesson study showed that he developed his insight on science process skills would develop students constructing science knowledge and characteristic of reasonable person. Therefore he designed his lesson to focus on science process skills and collaborative working. It was his opportunity to try new ideas of supporting science process and thinking skills to the students.

2.5.4 Boon Had More Insight of Inquiry and Reflection to Support Students' Learning in the Second Metaphor

Boon had view consistent with student-centered and inquiry teaching from beginning. His first metaphor "teacher as the sun" focused inquiry in the aspect of thinking skills for enhancing students constructing their own knowledge. Teacher's role was centered on preparing good environment for student readiness. He focused on facilitating the students' feeling of friendly and discipline. The second metaphor "teacher as a mirror" showed that he had deeper insight of inquiry teaching in aspect of developing students to be reflective practitioner who could construct and evaluate themselves.

2.5.5 Inquiry and Reflection Was the Factors Impact to Boon's Professional Development

Boon reflected in many evidence that were metaphor, journal entries in the modified lesson study, and his classroom case writing. He believed that reflection is the important process to help person developing in better practice. He found the effective of reflection enhancing students thinking during their own learning. He noticed himself that he could develop his teaching through the process of reflection on himself and with peers during the professional development.

Conclusion of Boon's Growth

Boon's science teaching initially was student-centered approach which more emphasized students' communication, but less science process skills. He adopted listening, thinking, questioning, and writing for science learning instead of hands-on activity, because the problems of lacking science equipments in school for science experiment. He believed that the good and warm relationship to the students would enhance students confident in teacher which help teacher in classroom management. He also believed that students' explanation was the most important for his classroom. It was important for him to encourage students to talk.

Boon developed an understanding of inquiry through direct experience with the 5E inquiry learning model in the three day workshop and reflection on written cases. The reflective process was beneficial in providing the opportunity to think about inquiry dilemmas and alternative solutions. During reaction on case-based pedagogy, he constructed many aspects of inquiry including: use small group discussion, facilitating students' collaborative work, encouraging students to respect on each other's ideas, making clear for objectives of students' work and making sure that students know, and assessing on product and process to make sure of students' learning. Boon applied his new understanding of inquiry into his classroom practice. He almost developed his teaching practice in high level of inquiry in every step of 5E lessons. There were some aspects which he could not developed the high level of inquiry teaching such as demonstrating the experiment of "rock formation." Because he did not sure about safety for students with fire in the experiment.

After applying knowledge of inquiry in her practice, Boon demonstrated a change in a more focusing of scientific process skills such as formulating questions, explaining of ideas, observing and recording data, communicating ideas, and evaluating explanation. Moreover, Boon second metaphor “teacher as a mirror” reflected the important of teacher’s role in facilitator for student to inquiry their own knowledge and supporting students to evaluate themselves.

3. Cross Cases of Yanee and Boon

In this chapter, the findings from Yanee and Boon were analyzed across cases to find out the pattern of development through this professional development. The results of crossing Yanee and Boon cases identified the patterns of their development on three main topics of understanding of inquiry, practice of inquiry teaching in authentic classroom, and the factors supporting teacher learning and practicing of inquiry approach

3.1 Teachers’ Understanding of Inquiry

Yanee and Boon presented the development in the understanding of inquiry. According to the evidence; journal entries after learning in 5E instructions, analytic 5E instructions worksheet, reflection on written cases, and classroom case writing, both of them had the common patterns in developing their understanding of inquiry as describing below.

3.1.1. Aspects of Inquiry Developed from the Analysis of 5E Earth Science Instructions

There were some similar patterns of Yanee and Boon development on understanding of inquiry. They had the same focused points on student learning in 5E inquiry constructing their own knowledge.

A. Same Goals for Students Constructing Knowledge

Yanee and Boon emphasized on students constructing their own knowledge through hands-on activities. They concerned on the interesting activity which enhanced students’ enthusiasm and fun together with science knowledge.

B. **Students' Discussion Important Activity Enhancing Students Higher Thinking**

Yanee and Boon focused on using discussion for enhancing students developing higher thinking such as analytical and synthesized thinking. They thought that teacher could provide more information after students presenting ideas. It was also beneficial for students correct understanding or making decision.

3.1.2 Refining the Understanding of Inquiry through Case-Based Pedagogy

The finding from analyzing data of participating in 5E instructions showed that Yanee and Boon developed the general aspects about understanding of inquiry. The evidence from reflecting on two written cases showed that they could refine their general aspects about understanding of inquiry which presenting in the common patterns as follows.

A. Thinking of Inquiry Technique Before Authentic Teaching in Classroom

Yanee and Boon identified the using of some techniques for enhancing inquiry in their classroom. There were techniques or strategies presented in their narratives: small group discussion with respect on each other, collaborative work; scaffolding students' conceptions from alternative concepts; assess students on process of working on their description; make clear for objectives of students' work; and make sure that students know.

B. Express the Possibility of the Teachers' Role for Inquiry Teaching

Yanee and Boon thought that teacher should have role to enhance students constructing knowledge. They mentioned about the role of teacher for inquiry during reflecting on two written cases. Boon focused the teacher’s role in facilitating of students’ working by explicate students understanding on their work. Yanee focused the role of moderator who motivate students’ conversation.

3.2 Teacher Inquiry Teaching in Authentic Classroom

3.2.1 The Lesson Plans with Inquiry Aspects Designed by Teachers

After the Thamma School team made agreement on the goals for student development and the topics for the modified lesson study. The patterns of three lessons in the “mystery of the earth crust” unit were first design by Yanee. She brought to Boon for editing for aspects in each step of 5E. Later, this unit were taken to the meeting of Thamma school team to consider on the objectives, activities, and assessment before implementing. Therefore both of Yanee and Boon mentioned that designing the lesson plan by themselves enhancing the use of inquiry understanding into practice.

Three lessons were similar activities in each step of 5E instruction which Yanee and Boon agreed on the inquiry aspects to enhance students learning. They started engagement by sparking the students’ curiosity with things around them such as the map, soils, sand, and rock in the school. Next, students explored on their curiosity with less guide dance in the earth crust and rock lessons and without guide dance in the soil lesson. Then every groups in the classroom explained their own knowledge with discussion by teacher’s questions leading to the common scientific knowledge. After that, students connected their understanding with teacher facilitating for demonstration or discussion. The assessment tools were worksheet, group work, and rubrics for explanation.

3.2.2 Teachers' Teaching Supported Students' Learning to Be More Inquiry-Oriented

A. Same Things that Yanee and Boon Concern for Designing Lesson

Yanee and Boon expressed their need to develop students' thinking skill and expressing ideas. They worked together on using science process skills and expressing opinion with group discussion. In both classroom presenting similar evidence of student learning. Students presented curiosity and questions, investigated to finding the answers of questions, explained the findings in their own words, connected knowledge to related knowledge, and evaluate their learning by themselves.

B. Different Teaching Styles in Their Somewhat Inquiry Teaching and Obstacles for Not Fully Inquiry

Even Yanee and Boon felt success on their inquiry teaching, their lessons were somewhat inquiry which teacher took action for students' understanding. Especially in exploration of the earth crust and rock lessons, teachers provides guide dance for helping students observation. In elaboration/extension step, teachers also conducted students' ways of connecting the knowledge to related knowledge. Yanee were not confident in students that they could explain correctly the scientific knowledge. Therefore she always led students concluded with her key words. Boon gave suggestion to Yanee to improve this weak point. He was successful to enhance students concluded with their own words correctly with scientific knowledge. Boon kept in mind about making students understanding in objectives and concentrate on their works. He always kept motivating on the important points which students should notice in their works and asked feedback from students. This was the reflective process which Boon emphasized to be happened in students.

3.2.3 Impact of Narrative Knowledge on Inquiry Teaching

A. The Different Views of Teaching Impacted on Teachers Actual Practice

The evidence from the first metaphors of two teachers showed that they had different view on teaching. Yanee's first metaphor was "teacher as a magician." She held the teacher-centered approach which students were perceived as the knowledge receiver from teacher, because they had low ability in thinking. This view had impacted on Yanee's teaching during the modified lesson study. She did not wait long for students' answer and sometimes she said the important key points on scientific knowledge for leading students conclusion. In contrast, Boon's first metaphor was reflected his view in the student-centered teaching. He focused on supporting student thinking skills. Supporting students constructing their own knowledge was a hard work for teacher, but he would tried his best in perfectly way as the sun keeping it's role. His view of student-centered approach impacted to the practice in the modified lesson study. He gave suggestion to Yanee to improve her inquiry to be more inquiry. He also demonstrated higher inquiry for enhancing students explanation.

B. Narrative Knowledge from Case-Based Pedagogy Influenced the Development of Higher Level of Inquiry

The level teacher inquiry teaching in this study depended on the dominance of students taking action in their own learning. Yanee and Boon developed the aspects of inquiry which relevant to student-centered approach during reflecting on two written cases. The dilemmas on these two written cases induced them to think about the effective ways to encourage students learning with inquiry environment. According to their actual practice in classroom, they could bring their knowledge of teaching to support their aspects of inquiry that were using of small group discussion with respect on each other, collaborative work, scaffolding students' conceptions from alternative concepts, assess students on process of working on their description, make clear for objectives of students' work, and make sure that students know. These techniques were found in their narrative knowledge that they constructed during workshop.

C. The Post-narratives Were Reflected the Development of Teacher Inquiry Teaching

After participating in the professional development, both teachers constructed their own narratives on the second metaphor and the classroom case writing. The results of Yanee's narrative knowledge hidden in her second metaphor and her classroom case writing changed to be student-centered approach which reflected from her own experience of inquiry teaching. In Boon case, his post-narratives were presented his viewed in student-centered approach. There was not big change of his practice, but there reflected his deeper insight of effective inquiry teaching incorporated with reflective process to enhance students thinking and constructing their own knowledge.

Conclusion the Cases of Yanee and Boon

Yanee and Boon used the understanding that their constructed in the workshop into their practice. They developed three lessons by themselves. These lessons were similar patterns of activities in each step of 5E inquiry. Their understanding of inquiry were constructed on their participating in the 5E instructions and reflecting on two writing cases. Both teachers accepted the new inquiry concepts as a good technique for enhancing students construction of knowledge. They applied these techniques to the lesson plans. The evidence of their practice on three lessons presented that they could improve their inquiry teaching to support students learning by themselves.

Common Findings of Four Cases

Common findings were derived from the analyzed results of four cases on their understanding of inquiry and inquiry practice development during the professional development. The common themes emerged in the findings are presented below.

1. Things to Concern about Teachers

1.1 The Teachers Entered to the Professional Development with Different Views about Inquiry

Based on the initial interview before workshop (July, 2006) and the first metaphor during the workshop (November, 2006) of four cases, they had the different views about inquiry. They knew that inquiry was a technique which enhances students to construct their own knowledge, but they held different views on details of inquiry teaching. There was only Boon held the inquiry views emphasized student-centered approach. He mentioned in both interview and the first metaphor that students should learn by themselves. He did not use lesson plans, text book, or advance science experience. He focused on students' processes of knowledge construction by listening (observing), thinking, questioning, and writing. Keaw was the teacher who had changed view from teacher-centered teaching presenting on the initial interview to student-centered teaching during reflection on her first metaphor. Initially, she held the view that students were low thinking ability, therefore, she had to control them to learn. However, she became accepting that students had their own way of learning, but they needed teacher to consider on the results of learning also give a hand to correct their misunderstanding. The other two cases, Pim and Yanee, held the strong views of teacher-centered teaching on both initial interview and the first metaphor. They thought that their students were too weak in thinking ability, therefore they needed teacher direction to help they understand the science concept. Pim and Yanee preferred to follow textbooks which help them to conduct students learning.

1.2 Teachers Were Different Ideas of Inquiry Teaching

Narrative tools in this study were not only revealing four teachers story in teaching, but also explicating their knowledge hidden in the story which called "narrative knowledge." This knowledge were used to tell us about teachers understanding of inquiry teaching and learning which they presented in their practice or experience. According to the analyzed data of narratives from four cases, they gradually held the different narrative understandings of inquiry in many aspects of knowledge of curriculum, knowledge of instruction, knowledge of subject matter, knowledge of self, and knowledge of milieu. The findings from teachers' initial interview and metaphors of all cases presented that teachers held the different teaching styles which effected by their ideas of teaching.

2. Professional Development Effected on Teachers

2.1 Change in Understanding of Inquiry

The almost knowledge that teachers developed during the professional development was about knowledge of instruction. The important knowledge of instruction which four cases developed were about techniques or strategies to enhance students constructing their own knowledge. These techniques and strategies were group discussion, finding students prior knowledge and misconception to scaffolding or conceptual change to scientific knowledge, evaluating student learning product and process, giving opportunity for them to evaluate themselves, changing teacher's role to be moderator or facilitator which reflected the more student-centered approach.

Other developed narrative knowledge were knowledge of curriculum, knowledge of subject mater, knowledge of self, and knowledge of milieu. Teachers changed their knowledge curriculum from content-based curriculum to be more consistently on students and the problems in the classroom. Some developed knowledge of curriculum were lesson plans which was focusing on science process skills and student thinking, improving utilizing of curriculum book, designing objectives of the lesson more relevant to students and teacher reflecting on the whole process of curriculum development in order to improve it. About knowledge of subject matter, teachers developed their knowledge of earth science concepts through the process of inquiry for their own lesson designing. The knowledge of milieu was developed as they realized that collaborative work between peers was value for deeper insight of effective inquiry and improving individual teaching. All teachers had better about knowledge of self. They realized the value of being facilitator who support students to construct knowledge. They had confidence on continue using of 5E inquiry.

2.2 Change in Beliefs of Teaching

Teachers' beliefs changed after participating in the reflective, inquiry-based professional development by compare teachers' beliefs of teaching from the first and second metaphor. Pim and Yanee changed their beliefs from teacher-centered to student-centered teaching and learning. Keaw and Boon held the belief of student-centered approach from the beginning. They developed to have the views which enhanced students to direct their own learning. Keaw improved her belief of teaching as coaching to be more facilitating. Boon improved his belief of teaching to more focus on using reflective process in his classroom to help learners constructed and evaluated their own knowledge. The findings from all teachers also presented that they saw the value of inquiry teaching which they had to work hard to prepare themselves as facilitators not the giver of information.

2.3 Change in Practice

The study found that all cases had changes in the inquiry practice. All teachers could constructed the understanding of inquiry from direct experience in 5E earth science of the workshop. They had the refine understanding of inquiry from reflecting on two written cases. Focusing on their practices, all teachers changed teaching to be more student-centered approach by translating knowledge into new practice.

3. The Characteristics of Reflective, Inquiry-Based Professional Development Model Enhanced Teacher Change

3.1 Inquiry Features of the Professional Development Were Key Activities for Developing the Understanding of Inquiry

The authentic experience on inquiry in 5E earth science instruction supported teachers to learn the earth science concepts. Moreover, they could insight how inquiry lesson conducted. The other inquiry process involving in this professional development model was the inquiry through the modified lesson study. Teachers had opportunity to improve inquiry in lesson designing and implementing throughout formulating the questions of their lesson plans, investigating to design the good lesson plan by self reading and group discussion, creating lesson plans, implement the lesson plans, evaluating the lesson plans and refining the lesson plans. The findings from their inquiry on the modified lesson study showed that they succeeded, were proud, and tended to use inquiry by themselves in the future. Therefore lesson study could support inquiry approach in the professional development in the sustaining way.

3.2 Reflecting Features of the Professional Development Model Were Key Activities for Developing the Understanding of Inquiry

The process of reflection with others and self-reflection enhanced teachers to construct the inquiry conception. The reflection process provided many opportunities that were (a) after experience in the 5E earth science instruction, (b) on case-base pedagogy, (c) every steps of the modified lesson study, (d) on the metaphor and the classroom cases, and (e) journal writing. The reflective thinking supported teachers to be active practitioners who thought back on their experience and were ready to improve their teaching practice. The teachers presented their teaching problems from their metaphor. They realized the good aspects of inquiry through analyzing their practice of 5E earth science instruction in the workshop. They refined their inquiry conception which constructed during 5E earth science instruction through reflecting the case-based pedagogy. They thought back on their own experience, tried to solve problem with new ideas of inquiry conception, and discuss for evaluate the results.

3.3 Sustain Contact on Teachers' Implementing New Ideas

3.3.1 The Integration of Inquiry Understanding into Lesson Designing

The four cases integrated the understanding of inquiry into their own lesson plans. The evidence of the goals of each school team emphasized student science process skills, student thinking, and collaborative work. Their lesson plans were designed to utilize many activities which enhanced students on science process, thinking, and collaborative working skills. They integrated all aspects of narrative knowledge that they developed on workshop into lesson designing.

3.3.2 The Integration of Inquiry Understanding into Teaching Practice

The findings of teaching practice showed that four case study teachers can integrate the understanding of inquiry into their teaching practice. All cases succeeded on integrating highest level of inquiry in the engagement, explanation, and evaluation steps. The left two steps of explanation and elaboration/extension were designed with the lower level of inquiry. In the exploration step, all teachers thought about providing protocols for student investigation. However, there were different practice between each team of the modified lesson study. Yanee and Boon integrated better inquiry teaching for investigation than Pim and Keaw. In the lessons of both teachers, Pim and Keaw, presented the lowest level of inquiry in students' investigation. The reason of not fully inquiry of four teachers' lessons reflected that teachers had strong belief of the low thinking ability of student to conduct their own experiment. Another interesting concern on the integration of inquiry understanding into four teachers' practices was about waiting time for students' thinking, questioning, or explanation. The evidence from classroom observation found that three teachers who are Pim, Keaw, and Boon had the higher inquiry level in supporting students' explanation, while Yanee had lower level. It because Yanee had lower patient on waiting students' answer. However Boon gave the suggestion to her. And she could improve waiting time and providing helping questions for students' explanation.

3.4 Peer Collaborative Working Supported Teachers' Learning and Practicing of Inquiry Approach

Peer collaborative working was a factor helping teacher to change their teaching practice. The important feature of peer collaborative working was the process for facilitating teacher's conceptualizing and practicing the inquiry teaching along the way of professional development. During the workshop, teachers were supported to work in group. Teachers were supported to discuss with peers for questioning, answering, and presenting their ideas. They also work collaboratively in every activities for finishing the work on time. During the modified lesson study, teachers also worked together. They shared their knowledge, gave the suggestion, and supported each other to practice on the inquiry teaching.

3.5 The Integration of Specific Needs of Teachers for Supporting Their Professional Development

Teachers were enthusiasm to try new ideas of inquiry into actual classroom. It was because they wished that inquiry teaching would help them to solve problem about low thinking ability of the students. They did not follow others' way of teaching, instead they created their own way of teaching. This professional development model realized about the common problems and needs of the teachers. Therefore, teachers were satisfied to participated on professional development and presented the changes to be more inquiry and student-centered approach.

Summary

The impact of the professional development model emphasizing reflective and inquiry-based approach had strong influence on the teachers' narrative knowledge (the understanding of inquiry and views on inquiry teaching) construction. The learning activities on authentic experiencing in 5E inquiry instruction and reflecting on teachers' narratives encouraged the teachers developing their understanding of inquiry. Especially, teachers' written case reaction reflected narrative knowledge which teachers' conceptualized the understanding of inquiry from the problems on the written cases. Additionally, the impact of the professional development model was found in teachers practice in their own classroom. All teachers could bring constructed narrative knowledge into practice for designing the inquiry lesson plans and implementing lessons in the actual classroom. All teachers conducted 5E inquiry instruction with high level of inquiry teaching for engagement, explanation, and evaluation by incorporating their understanding of inquiry. However, some steps of exploration and elaboration/extension in Pim and Keaw teaching were lower level of inquiry teaching. Teachers held the strong belief of difficulties for young students conducting experiment by themselves. In summary, factors of this study supported teachers developing the understanding of inquiry and inquiry teaching were (a) teachers' views (beliefs) in teaching; (b) setting of inquiry and reflective process; (c) collaborative working with peers; (d) teachers' specific need in supporting students' learning. In Chapter 7, conclusions, discussion and recommendation of the research findings of this study were presented.

CHAPTER VII

CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

Introduction

This chapter presents conclusions and a discussion of the results of this research study. The recommendations follow the conclusions and the discussion. The first section presents conclusions in relation to the main research questions. In the second section illustrates the discussion of this study. The findings from facilitating and impeding teachers' changes of the reflective, inquiry-based professional development model are discussed. In the last section of this chapter, recommendations in the professional development of teachers are introduced for further research studies.

This research study was initially designed to promote learner-centered educational strategies for Thai elementary science teachers. The inquiry learning and reflective processes were specific strategies believed to enhance a learner-centered approach. Inquiry and reflection were incorporated with the expectation that this study would be beneficial for teachers attempting to construct an understanding of inquiry and implementing inquiry practices in actual classrooms. The research study was conducted in response to the following research questions:

1. What are Thai elementary science teachers' professional development needs?

2. What happens when a professional development model for Thai elementary science teachers is planned, translated, and experienced?

2.1 How are characteristics of a professional development model conceptualized, designed and implemented to facilitate elementary science teachers' learning based on notions of reflective and inquiry-based practice?

2.2 How does teachers’ narrative knowledge with respect to the teaching of earth science evolve during a professional development experience?

2.3 How do teachers translate what they learn through the professional development experience into classroom practice?

Conclusions

1. Conclusions in Relation to the First Research Question

The first research question aimed to explore the professional development needs of elementary science teachers in the Pathum Thani province of Thailand. Teachers’ professional development needs and their problems in current teaching were looked at as the change elements integrated in the professional development model which enhanced teachers through positive changes in the professional development. Two instruments, the questionnaire of teacher teaching and professional development needs and interviews of teachers and professional development needs, were developed and utilized to assess teachers’ professional development needs.

The findings of this research question revealed that teachers presented similar professional development needs from both instruments. The findings of the questionnaire found that the majority of 95 Pathum Thani teachers needed to develop in the areas of teaching techniques, curriculum development, and learning media construction.

The results of teachers’ professional development needs were consistent with a not fully student-centered approach in their current teaching situation. They mentioned in the same questionnaire that they could practice science curriculum development, lesson introduction, activities in science lessons, use of media and evaluation according to the National Education Act B.E. 2542 (1999) and Amendments at a moderate level consistent with a student-centered approach.

The findings from the interview of four case studied teachers reflected the impacts and difficulties in student-centered teaching. Some mentioned issues were school policy effects on teachers' planning for science instruction and low thinking ability of their students. Science teachers had different styles for designing activities to compliment their lesson plans. If the school did not focus on science subjects, teachers did not prepare much for their science lesson plans. Most of them followed science textbooks. The students did not create their own investigations from their curiosity. They followed instruction in the textbooks and teachers' directions and they were unable to explain their own ideas after doing activities. The results of each teacher's interview was consistent with the majority of Pathum Thani teachers' professional development needs in the questionnaire. In summary, Pathum Thani teachers felt they needed further professional learning to help them analyze curriculum, engage students' enthusiasm and curiosity, learn new pedagogical and techniques, science content knowledge, develop new ideas for assessment, and gain new ideas on using other learning media and resources besides textbooks.

2. Conclusions in Relation to the Second Research Question

The findings in relation to the research question, "What happens when a professional development model for Thai elementary science teachers is planned, translated, and experienced?" were concluded in terms of planning and using of the model as follows.

2.1 What Happened in Terms of Planning of the Professional Development Model?

Findings in relation to the exploration of teachers' professional needs and literature review were utilized to generate guiding principles for the professional development model. The literature review documents consisted of educational guidelines in the National Education Act B.E. 2542 (1999) and Amendments and existing literature about Thai science standards, teacher knowledge, inquiry approaches to teacher development, reflective approaches to teacher development, and professional growth and teacher change documents. The results of analyzing

Pathum Thani teachers' professional development needs and corresponding literature led to four guiding principles for the reflective, inquiry-based professional development model:

1. Teachers as learners: the learner-centered approach
2. Teachers as reflective practitioners
3. Teachers constructing knowledge through inquiry process
4. Integrating elements of teacher change and growth

The reflective, inquiry-based professional development model aimed to investigate the effect of developing and using a professional development model for upper-elementary science teachers which emphasized a reflection and inquiry based approach. The model also aimed to support teachers' understanding and practice of inquiry teaching. This professional development model was designed with emphasis on linking theory and practice of science teacher learning. Teachers in this study were committed to practice new ideas by participating in a modified lesson study after a short period of training.

The specific professional development needs of Pathum Thani teachers were incorporated in the design of the reflective, inquiry-based professional development in terms of training activities in the workshop and collaborative work in the modified lesson study. The training activities were designed to serve the Pathum Thani teachers' professional development needs by improving the following teaching techniques: engaging students' interest and curiosity, supporting students' thinking skills, varying hands-on and mind-on activities, problem solving, experiment combined with discussion, and using local resources to teach science. The modified lesson study was designed to support the Pathum Thani teachers' professional development needs in relation to curriculum, focusing on analyzing core curriculum and writing effective lesson plans, enhancing student-centered approaches, writing model lesson plans, and collaboratively working on planning lessons.

The training activities in the three day workshop were designed with six 5E earth science lessons and two case-based pedagogy lessons. These activities focused on discussion, reflection, and collaboration in small groups. The activities in the modified lesson study focused on collaboration and reflection within each school team for designing, teaching, revising, and re-teaching lesson plans in their school specific contexts. Teacher learning was evaluated in the context of the professional development experience by artifacts, worksheets, journal entries, lesson plans, written classroom cases, and metaphors. A handbook for the reflective, inquiry-based professional development model was comprised of the instructor's manual section and the teachers' activities section. The instructor's manual section contained instructor information sheets and activity sheets. The teachers' activities section contained worksheets, journal entries, reflections on written cases and metaphor worksheets. The quality of the handbook was assured by two supervisors of this study and three experts. The experts were two earth scientists and one expert elementary science teacher.

2.2 What Is Learned through the Professional Development Model?

The process of implementing the reflective, inquiry-based professional development model was meaningful to the teachers who translated what they experienced into practice. The results of translating the professional development into classroom practice are summarized in terms of the role of the researcher and teachers, the variety of teachers' initial beliefs about teaching and teachers' understanding of inquiry.

2.2.1 The Role of Researcher and Teachers

The researcher participated as an observer who took responsibility as instructor of the three day workshop with sessions on 5E inquiry instructions, case-based pedagogy lessons, and metaphor reflections. Videotape recordings were employed during the three day workshop. In the modified lesson study session, the researcher was a facilitator who conducted the processes of lesson planning, lesson observation, reflection and discussion. The modified lesson study experience was used for teachers translating their understanding of inquiry into practice after participating in the short term workshop. The meetings of the modified lesson study happened separately between the two schools for the purposes of: (a) introducing the lesson study to the team, (b) designing and adjusting lesson plans, (c) classroom observation, (d) revising the lessons, and (e) re-teaching the lessons. In the modified lesson study, the researcher participated as an observer and acted as a facilitator for the four case study teachers participating in the process of planning, observation, and reflection sessions. Mostly the role of the researcher was to set the responsibility for the team, such as, asking questions that motivated teachers to reflect on their ideas. Therefore the researcher influenced the understanding, practice, and views or beliefs of the teacher members of the team in minor ways only, by the nature of the questions teacher asked.

2.2.2 Teachers' Initial Beliefs about Teaching Were Varied

The initial understandings of inquiry and beliefs about teaching of each teacher were inferred at the beginning of the workshop. The findings from interviews and metaphors showed that teachers had different understandings and beliefs of inquiry at the beginning phase of professional development. Pim and Yanee had an understanding of inquiry consistent with teacher-centered teaching as reflected in both of their interviews and metaphors. Keaw presented in her interview an understanding of inquiry that was consistent with a teacher-centered approach. Her metaphor, on the other hand, reflected a view of teaching from a student-centered approach. Boon's beliefs about student-centered teaching were the strongest; his interview and metaphor reflected a consistent understanding of student-centered organizational experiences.

2.2.3 Understanding of Inquiry through Participation in an Inquiry Learning Setting

It was found that the four case study teachers developed an understanding of inquiry more related to a student-centered approach through their participation in the professional development experience. Inquiry thinking helped them construct earth science concepts and pedagogical understandings of how to teach inquiry through the 5E inquiry model. After experiencing 5E earth science inquiry learning, they could identify the characteristics of activities that fit each step of 5E inquiry. They realized teachers' and students' roles in enhanced inquiry learning happen in each step of 5E inquiry.

2.2.4 Understanding of Inquiry through Reflective Setting

The teachers constructed a narrative understanding of inquiry by reflecting on their ideas to solve problems presented in the written cases. Their case reactions reflected knowledge of instruction which enhanced their inquiry teaching. This narrative understanding of inquiry dealt with the following issues: (a) using small group discussion for many purposes such as enhancing conceptual change, students' presentation and exchange of ideas, (b) using questions to explicate student understanding, (c) scaffolding students' conceptions from alternative concepts, (d) formative assessment in terms of assessing learning products and processes, evaluating students' learning processes, and students' description of how to work, (e) making clear objectives for students' work and making sure that students understand, and (f) teachers' roles as both facilitator and moderator.

2.2.5 Understanding Curriculum and Instruction through Lesson Study

Teachers found that 5E inquiry instruction was a good technique to enhance student learning. The results also showed that teachers improved in their inquiry teaching through lesson study in 4 ways: 1) lesson study was effective in sustaining teacher development of inquiry lessons, 2) peer collaboration was valuable in improving inquiry teaching, 3) teachers utilized many curriculum books to prepare to engage in lesson study more effectively, and 4) their experience in science teaching was very beneficial for designing inquiry activities and testing them out in the classroom as part of the lesson study process.

2.3 What Happens When the Professional Development Model Is Experienced?

The processes of implementing the reflective, inquiry-based professional development model were meaningful in terms of what teachers derived and what they experienced in authentic classrooms.

2.3.1 Teachers Difficultly in Immediately Changing Their Practice

Only Pim and Keaw allowed the researcher to observe their initial practice in classrooms before the modified lesson study. The findings of their initial classroom teaching confirmed that both teachers taught with a teacher-centered approach. Their initial classroom practice presented low levels of inquiry teaching in many aspects. Both teachers had an understanding of inquiry from training in the three day workshop, but their classroom practice did not immediately change to a student-centered approach after training. In the cases of Yanee and Boon, the researcher was not allowed to observe their initial practice.

2.3.2 Teachers Gradually Changed Their Practice

The case study teachers had a gradual change in their practice. All four teachers developed better, but not fully cultivated, inquiry teaching. They developed and implemented their lessons in somewhat student-centered ways. In Pim and Keaw's case, their inquiry teaching was at a high level in some areas. These areas were engagement, explanation, and evaluation. In the other two areas, exploration and elaboration/extension, they demonstrated low levels of inquiry in practice. Pim and Keaw developed their own lessons in similar steps of 5E inquiry: (a) Engagement - teacher motivating students to express prior knowledge and formulate questions or hypothesis, (b) Exploration - students investigating following the teachers' procedures, (c) Explanation - explaining and discussing students' own understanding with teacher's facilitation, (d) Elaboration/extension - teacher providing opportunities for students to apply knowledge in similar situations, and (e) Evaluation - teacher using many assessment tools including student presentations, experiment worksheets, constructing models, and collaborative group work.

In the cases of Yanee and Boon, their inquiry teaching was at a high level in every step, but Yanee often involved herself in students' thinking. She frequently told key words to students to help them create their own explanation, but she became more student-centered in her teaching by allowing more wait time for students' answers and making sure that students understood on what they did before explaining their own conclusions. Yanee and Boon developed lessons with common activities in the steps of 5E inquiry as follows: (a) Engagement - teacher using activities to increase curiosity of when students expressed prior knowledge and asked questions, (b) Exploration - students investigating with less teacher guidance, (c) Explanation - students explaining their own understanding in a group with teacher facilitation, (d) Elaboration/extension - teacher connecting students knowledge to related knowledge with additional activities, and (e) Evaluation - teacher using assessment tools that include rubrics on student presentations, investigation worksheets, students' construction of products and collaborative group work.

2.3.3 Teachers Changed Their Beliefs to Be More Inquiry and Student-Centered after the Modified Lesson Study

At the end of the professional development, the teachers were asked to create their own second metaphors and classroom case writing. Teachers' understanding and beliefs of inquiry were reflected in their narratives which showed that all teachers had positive changes in their understandings and beliefs of inquiry. They presented a development of narrative understanding of inquiry consistent with student-centered teaching in the actual classroom. They reflected on their beliefs behind their practice through the expression of narrative writing. However, the changes of beliefs of each teacher were different in their details.

Pim changed her understanding of inquiry from a teacher-centered to a more student-centered approach. Her beliefs about science teaching presented as reflected in her second metaphor, "teacher as a director," reflected some aspects of teacher-centered instruction. She had the strong belief that low thinking ability students needed her direction for their learning, while high thinking ability students could conduct their own inquiry learning.

Keaw changed her understanding of inquiry from a somewhat teacher-centered to a student-centered approach. Her beliefs about teaching in the second metaphor, “teacher as what students want,” reflected a student-centered approach. She had views that students were persons who could create their own learning along with facilitation from the teacher.

Yanee changed her understanding and beliefs about inquiry from a teacher-centered to a student-centered approach. Her beliefs as reflected in her second metaphor, “teacher as a rudder for life,” reflected the idea that students could learn and be successful by themselves. The teacher was a helper for them to reach success more easily. In the sense of student science conceptions, Yanee felt that teachers help students by giving suggestions on their explanations to direct conceptual changes.

Boon did not demonstrate much change in his understanding and belief of inquiry because he had an initial understanding and belief of inquiry as a student-centered approach. He changed mostly in his practice in regards to a more scientific process for students. However, Boon's beliefs of teaching developed by not only focusing on students’ constructing knowledge, but also students evaluating their own learning and themselves through the process of reflection.

Discussion

1. Discussion of the First Research Question

Pathum Thani's current teaching status had improved according to the National Education Act B.E. 2542 (1999) and Amendments, but their teaching was not fully student-centered in the topics of (a) science curriculum development, (b) lesson introduction, (c) activities in science lessons, (d) use of media, and (e) evaluation. This finding was consistent with the findings of the study of Chareaonwongsuk *et al*. (2005) in which Thai teachers developed their teaching during the educational reform period (A.D 2542-2547), but their teaching was not fully successful as a student-centered approach. This result suggested that short term training was not appropriate for effective change to student-centered teaching and learning. Therefore the professional development model of this study was designed to provide teachers opportunities to gain new knowledge and skills, reflect on changes in their teaching and increase their abilities over time (Kayler, 2003; Shield *et al*., 1998; and Weiss *et al*., 1998) as a follow-up section of short term training to facilitate teachers' change and growth. Moreover, current problems and teachers' needs in professional development which were beneficial for effective teacher professional development were incorporated (Department of General Education, 1992).

The majority of Pathum Thani science teachers needed professional development in every topic even though they had experience in training during A.D 2545-2548. Most of their training was in the form of short term workshops for a few days. The teachers' needs for professional development were consistent with suggestions that teachers should improve their student-center teaching abilities. The suggested professional development areas were analyzing curriculum, engaging students' enthusiasm and curiosity (Tongchumnum, 2004), teaching techniques, science content knowledge, assessment (Srisa-ard *et al*., 2001; Cheangkool, 2006), and employment of other learning media and resources besides the textbooks, especially the media about information and communications technology (ICT) (Cheangkool, 2006).

2. Discussion of the Second Research Question

The reflective and inquiry processes of the reflective/inquiry professional development model had positive effects on increased teacher knowledge, skills, and beliefs of inquiry teaching which led teachers' change in inquiry practice. The results of the processes of planning, translating and experiencing the reflective, inquiry-based professional development are discussed in terms of the effectiveness of the model according to the guiding principles, the factors facilitating the implementation of the model, and the factors impeding the implementation of the model.

The Effectiveness of the Reflective, Inquiry Professional Development Model

Four guiding principles were generated from the literature review. The effectiveness of this professional development model was considered in terms of teachers' change through the activities of the reflective, inquiry-based professional development model which was consistent with the guiding principles:

1. Teachers as Learners: The Learner-Centered Approach

The study found that the characteristics of regular teaching in the reflective, inquiry-based professional development model were consistent with a learner-centered approach found in many other studies. The reflective, inquiry-based professional development model enabled teachers to experience the types of instruction that they were asked to provide to their students. The activities in the 5E instructional model were ones that teachers could apply in their own settings, and could be used to facilitate discussions of students working in small groups which in turn could help the teachers transformed their own understanding (Lunsford, 2002; Songer *et al*., 2003; and Lee *et al*., 2004). The reflective, inquiry based instructional model also focused on the teachers' actions themselves. They were engaged interactively and collaboratively in training activities. Like their students, teachers learned by doing, collaborating with peers, reflecting, and planning classroom activities. The teachers were not just sitting and listening to the instructor but actively participating (Jenlink and Kinnucan-Welsch, 2001; Erickson *et al*., 2005; Rock and Wilson, 2005; and Saito *et al*., 2006).

2. Teachers as Reflective Practitioners

The findings from the second metaphors and classroom case writing revealed that teachers changed their beliefs of teaching to be more consistent with a student-centered approach. The factors effecting the change in beliefs were the design of reflective processes. The impact of reflection on belief change was consistent with many studies. The reflection in this study consisted of reflective tools such as metaphor, case reaction, and classroom case writing. Reflective processes of reflection with others and self-reflection were also employed. The reflective processes created the context of fundamental values and beliefs about teaching (Day, 1999; Lunsford, 2002; Lee *et al*., 2004). The reflective tools enhanced teachers' analysis of the portraits of narratives about their experiences through the use of a teacher knowledge framework (Mulholland and Wallace, 2005). Teachers' reflections on stories were especially effective with respect to clarifying and changing teachers' beliefs about teaching (Ritchie *et al*., 2006; Tippin *et al*., 2002; Mattingly, 1990). When teachers were asked to reflect on their metaphor, teaching, or cases in the classroom, a bridge was provided that revealed their values and beliefs about decisions in relation to their own teaching.

3. Teachers Constructing Knowledge through an Inquiry Process

In this study, the 5E inquiry model increased teachers' knowledge of subject matter and knowledge of pedagogy. The findings of this study were considered in terms of whether teachers' understanding of inquiry's effect on their teaching was consistent with studies focused on using inquiry techniques. Teachers' efforts to construct an understanding of science content and pedagogy were consistent with a study by Lunsford (2002), who used guided discovery and problem solving during a workshop. His study also found that teachers improved of both subject matter and pedagogy in inquiry teaching.

The findings from the analytic 5E earth science instruction worksheets and case reactions demonstrated that teachers developed an understanding of inquiry more consistent with a student-centered approach. The best understanding of inquiry must happen in an inquiry learning setting which enhances thinking focused on explanation building, prediction making, and integration of scientific ideas with problems in science. The results of an inquiry setting for professional, and its effect on teachers' understanding of student-centered learning was consistent with studies that create learning environments that utilize many techniques of inquiry (Lunsford, 2002; Windschitl, 2002; Songer *et al*., 2003; Lee *et al*., 2004; Crawford *et al*., 2005).

4. Integrating Elements of Teachers Change and Growth

There were three elements that enhanced teachers' change in beliefs and practice during participation in the reflective, inquiry-based professional development. These elements included: (a) an emphasis on the specific needs of teachers; (b) committing teachers to the practice of new ideas and evaluation in their own teaching context; and (c) team-building plus facilitation along with opportunities for extending new ideas.

4.1 Emphasizing the Specific Needs of Teachers

In terms of incorporating change elements, the reflective, inquiry-based professional development model recognized and addressed professional development needs of Pathum Thani teachers and the constraints teachers faced in their own schools. Similarly, other studies suggested the importance of integrating teachers’ needs to ensure that the professional development was meaningful and led the teachers to gain new knowledge, skills, and practices that helped students learn (Loucks-Horsley, Stiles, and Hewson, 1996; Brown, 2000; Loucks-Horsley *et al.*, 2003). The teachers’ changes in beliefs and practices were affected by activities that responded to their needs of developing teaching techniques, science content, and curriculum development. The case reaction as part of the professional development experience, helped teachers contemplate strategies that would engage students in discussion and self-evaluation. The 5E earth science instruction focused on helping teachers gain science content and an understanding of inquiry. The lesson study session provided an opportunity for curriculum analysis and lesson plan writing. Similar to the study of Brown (2000), teachers were eager to learn what they wanted to know. Teachers pursued their needs in professional development for self-direction and taking responsibility for enhancing students’ learning.

4.2 Committing Teachers to Practice New Ideas and Evaluation in Their Own Teaching Context

The lesson study was a site-based method which effectively provided follow-up for short term training in a school context. Teachers had gradually changed their beliefs and practice of inquiry through the elements of change and growth provided through lesson study. The teachers in this study used their new understanding of inquiry in real world applications. The results of teachers' growth in inquiry teaching, with their gradual changes through the reflective, inquiry-based professional development model, were influenced by the opportunity for classroom application. This finding was supported by many studies involving lesson study which suggested that this approach helps teachers engage in the gradual process of inquiry, build mastery of pedagogy, and build a team for collaborative work in the specific and situational problems of their authentic classroom (Lewis *et al*., 2004; Rock and Wilson, 2005; Saito *et al*., 2006). Formative evaluations such as observation, discussion after class and journal entries were conducted during the lesson study to help teachers improve their teaching. Teacher learning was assessed throughout the lesson study process in terms of the progress made toward meeting team goals of enhancing students' learning. This was similar to many studies that use formative evaluation to encourage teachers' improvement (Briscoe and Wells, 2002; Rock and Wilson, 2005; Saito *et al*., 2006).

4.3 Team-Building and Facilitating along with Opportunities for Extending New Ideas

The reflective, inquiry based professional development model was designed to provide opportunities for teachers to work collaboratively in a group, especially in the lesson study team. Through journal entries, teachers reflected on their personal experiences as members and facilitators of the team. Teachers developed new practices by trying new ideas and problem solving strategies in their classrooms, based on the suggestions and recommendations of team members. This study was consistent with other studies which suggested that facilitation in a team was an alternative form of professional development for transformation through personal growth and teamwork. Moreover, professional skills essential for team building were used in the lesson study process: these were essential for collaborative workers. These professional skills included communicating, listening, delegating, resolving conflicts, clarifying roles, and changing management, and were similar to team building skills found in other studies (Jenlink and Kinnucan-Welsch, 2001; Erickson *et al*., 2005).

Facilitating Factors of the Reflective, Inquiry-Based Professional Development Model

Three factors emerged that facilitated the implementation of reflective, inquiry-based professional development.

1. The Role Modeling in Becoming a Reflective Practitioner

Boon clearly highlighted the importance of participating in this from of professional learning. He emphasized the value of model and the facilitative role of questions. In his journal entries on the modified lesson study, his classroom case writing, and his second metaphor, Boon stressed that facilitation from the researcher through questions for reflection on practice enhanced his professional growth. He felt that he learned to be a facilitator to encourage students' reflection. Boon also directed his own reflection, developed through the explicit modeling of the facilitator. Through modeling, the teachers had a chance to be involved in looking at activities and learning by reflecting. This finding was consistent with other studies suggesting that role models had a positive impact on teachers learning how to teach (Kelly, 2000, Marion *et al*., 1999, and McGinnis, Watanabe and McDuffie, 2002).

2. Planning/Organization

This functional model of the professional development incorporated needs, inquiry learning, facilitation and collaboration on practices, and evaluation through reflection. It provided an organizational structure for teachers to balance their lesson development with core curriculum, their needs to enhance student learning and motivation, and the characteristics of the students. The field journal for reflection was an effective tool for helping teachers deliberate by themselves. These supporting factors were found in many studies which connected the success of teacher change in part to the impact of planning and organizing of the professional development model (Bruce, 1999; Lewis *et al.*, 2004; Erickson *et al.,* 2005).

3. Resources

Learning resources were provided to the teachers to support their use of inquiry activities in authentic classrooms. These learning resources were rock and mineral sets, globe models, textbooks and professional literature. This was very beneficial for schools where there was a lack of science equipment and laboratory space. Teachers used the text books and professional literature to prepare themselves with content knowledge and activities for inquiry. Teachers were glad to see their students interested and enthusiastic about inquiry lessons. It was important for the professional development model to prepare essential resources for working in schools. Many studies suggested that sometimes teachers needed to read and share professional literature to inform them of solutions to possible problems in their classrooms (Bruce, 1999; Rock and Wilson, 2005). This information was instrument in increasing their content knowledge and teaching techniques and strategies

Factors Constraining the Development and Implementation of the Reflective, Inquiry-Based Professional Development Model

Four factors emerged that impeded the implementation of the reflective, inquiry-based professional development.

1. Strong Belief about Students

The teachers' growth in practice with respect to inquiry teaching did not fully encompass a student-centered approach. The teachers constructed an understanding of inquiry through a student-centered approach consistently during training in the workshop. The main factor that inhibited their inquiry practice was their beliefs about students' low thinking abilities. All teachers thought that providing opportunities for students to think about questions, generate hypotheses, and discuss explanations could be successful. Yet they felt that having students design investigations based on hypotheses could prove extremely difficult for those with low thinking abilities. This necessitated more direct instruction from the teacher. This finding was consistent with the study of Fennema and Franke (1992), who found that teachers' knowledge of students' thinking was a major determinant of instruction and learning. While teachers' beliefs about teaching in this study changed from teacher-centered to more student-centered approach, their practice was not fully student-centered. Similar findings from other studies always found inconsistencies between teacher beliefs and teaching practice (Raymond, 1997; Bryan and Abell, 1999; Lemberger *et al.*, 1999; Veal, 2004).

2. Creating a Culture of Learning through Reflection and Collaboration for Teachers

Similarly to a study conducted by Rock and Wilson (2005), teachers initially felt inadequate in their abilities and comfort levels with peer coaching and critiquing. Even though the ground rules of the members' roles for engaging in the lesson study were discussed, these teachers found it difficult to critique one another. Some feared they would hurt other teachers' feelings. Some younger teachers did not feel comfortable providing feedback to more experienced teachers. In the Thai school context, teachers often work in an environment where external evaluation is made by administrators or national organizations rather than peers. Therefore, it was important to create a culture of learning through reflection and collaboration for teachers who engaged in the lesson study process. Examples of strategies involving reflection and collaboration for teachers could be group case reactions, microteaching with critiques, peer classroom observations and Open Lessons. These techniques could be initially incorporated in the lesson study format. Moreover, these strategies, like peer coaching, might need to be incorporated for the extended lesson study session without facilitation from the researcher. This additional training could enhance teachers confidence in their ability to self-direct and determine their own professional learning goals and select activities that might help them attain these goals for supporting their own professional development (Haggarty and Keith, 1995).

3. Other Constraints

Other factors that constrained the development and implementation of the reflective, inquiry-based professional development were a lack of collaboration with some administrators, curriculum content, and time. The teachers from the two schools mentioned how school policy affected their science lessons. In the Thai school context, teachers were familiar with conducting changes based on administrator's policies. Thai teachers were not familiar with intrinsic motivation concerning self direction. Most of them found it difficult to make changes because they were familiar with traditional professional development which was top-down and focused on being driven and observed by an expert. Likewise, other researchers (Loucks-Horsley, Stiles, and Hewson, 1996; Oliveri and Towery, 2005) found that engaging administrators and other stakeholders (the groups such as government administrator, resource, people, funding makers, the professional developers, and the community) was a concern in terms of promoting teachers' effective change. Another constraint was the curriculum content. Thai science curriculum contains many science topics for students to learn. The teachers in this study mentioned that it was difficult to plan an inquiry learning experience to respond to all science topics in the core curriculum because there were so many topics. Teaching inquiry effectively means that a teacher needs time to encourage students in their own investigations. Teachers need not only time for setting up the inquiry learning experience, but also time for their site-based professional development.

Recommendations

This research study was done in a unique professional development model with the reflective, inquiry-based approach with a specific group of teachers. The reflective, inquiry-based professional development model was conducted by the researcher who took the role as an instructor in three day workshop session and a facilitator of the modified lesson study component. The participants of three days workshop were 13 elementary science teachers from two schools in Pathum Thani province. Four case study teachers participated in the sustained contact modified lesson study for three months. The recommendations that emerge from this study are illustrated as follows.

1. Recommendations for Future Research

A better understanding of how to make the reflective, inquiry-based professional development model work in a variety of settings and contexts is needed. The findings of this study are not generalizable; however, the description of how the model of the reflective, inquiry-based professional development was implemented and the suggestions stemming from it may prove to be useful to others who choose to apply this model in their own context.

Further but similar studies of the reflective, inquiry-based professional development model should be conducted to support elementary science teachers in obtaining the highest level of inquiry, in accordance with the science teacher inquiry rubric (NRC, 2000; and Karen *et al*., 2004). This study proposes some suggestions in this regard. First, future studies should take into account the stakeholders, especially the administrators who provide the school's policy and evaluate teachers. Administrator "buy-in" could support teachers in their self-directed lesson study and sustain active engagement with the professional development model. Second, a longer – term study is needed to gauge how teachers change their beliefs and practice. In addition, other cases could be developed to cover different aspects of narrative knowledge such as knowledge of curriculum, knowledge of subject matter, knowledge of self, and knowledge of milieu. These new cases could be used to provide teacher opportunities for deeper discussions and written analysis. Moreover, teachers should be engaged in an environment of reflection and collaboration for extended periods of time. This would enhance teachers' abilities to engage in the process of collaboration among peers. Finally, future research needs to provide mechanisms for self directed learning, which requires time. This approach would enhance teacher learning on an individualized basis with little formal structure or support from outsiders. These individuals should participate in the professional development along with teachers so that they are committed to supporting new approaches to science teaching and learning.

2. Recommendations for Professional Development

In this study, there was success in facilitating change to "somewhat student-centered teaching" in all four teachers' practice. These teachers had a variety of beliefs from teacher-centered to student-centered teaching in the initial phases of the professional development. After fully participating in the reflective, inquiry-based professional development model teachers expressed beliefs more consistent with a student-centered approach. Even though these teachers did not fully demonstrate student-centered teaching, they presented changes in their beliefs about inquiry. This study proposes some recommendations needed for effective change in both of beliefs and practice of teachers. First, professional development needs to build strong connections between teachers' beliefs about teaching and learning and their actions (Tobin, Tippins, and Gallard, 1994). This study suggests that an effective strategy for connection of beliefs and actions is the reflective process. Second, in a professional development context, it will be important to define how to convince teachers of the value of high levels of inquiry such that they are confident that they are qualified to implement it. Jeanpierre, Oberhauser and Freeman (2005) emphasized that teachers need to understand the rationale and goals of desired changes. Additionally, Luft (2001) added that professional development programs should attend to the diverse behaviors and beliefs of each participant.

With respect to the lesson study, this professional development model needs to have someone serve as a facilitator to guide the process, organize resources, and assist in finding coverage for classrooms to allow for teacher planning, observations, and reflection/critiquing sessions. This study suggests the need to train all members in the lesson study team so that they are prepared to assume this role. It is important for all teachers to share in rotating the role of the facilitator in lesson study, so that opportunities and support for professional development happens for all teachers in the team.

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APPENDICES

Appendix A

Metaphor Protocols

Metaphor Protocols

Metaphor Protocol 1: The teachers' role in the science classroom (first metaphor of each teacher in the workshop)

Metaphors are one way we can think about teaching. Metaphors are comparisons that put an image into our heads and guide the way we approach the classroom. Teachers can use metaphors to describe their roles in the classroom, for example, "The teacher as a detective". Describe a metaphor that would be useful in describing your role and philosophy as a teacher of science. (See the example of metaphors in Appendix B)

Metaphor Protocol 2: Second metaphor of each teacher in the last day of the modified lesson study

This is your second opportunity to develop a metaphor that you can write to describe your role about science teaching and learning. You can think about the first metaphor(s) that you used and modify it as you think necessary. Or you can write about a new metaphor that better fits with your philosophy. Just think about "What is the best metaphor for describing your role and beliefs in science teaching and learning now?"

Appendix B

Example of Teaching Metaphor

Example of Teaching Metaphor

Metaphor 1: Teacher as a Detective

I think of a teacher as a detective. When detectives begin to solve cases everything is a mystery to them. They do not have enough information about the case at the beginning to be able to solve it. They need to find clues and other facts in order to help them put the pieces together. They put all of the clues together to help them build up to the answer. This reminds me a lot of teachers when they first meet their students. At the beginning of the school year, teachers do not know anything about their students. They have to find out information about how their students learn the best and also background information of each student because there is so much variation from child to child. This helps the teacher do the best she can do in order to meet the individual differences in the class. A science teacher needs to know the interests of his/her students in order to find the best way to teach the science concepts and facts. Also science teachers also teach the scientific method to the students. This also fits great with a detective because he/she needs to go through these steps in order to solve a mystery.

Another way science teachers are like detectives is because of the amount of time spent on their work. Detectives do not usually just work at certain times. They are constantly trying to find new information and building on this information. They are also always testing their guesses that they make in order to find more proof that these guesses are correct. Likewise, a science teacher is not through working at the end of the school day. He/she is constantly planning what type of experiments or other science activities that are going to be used during class time. It also takes a lot of time to try out these experiments to make sure they work, before being presented to the students. The teacher is doing the work around the clock, not just from 8.00 a.m. - 3.00 p.m. Most importantly, the detective spends this much time on the work usually because he loves doing it. Likewise, the science teacher chose to teach science because of her love for the subject. So she spends a lot of her time, whether in or out of school, deciding what to teach and how she plans to teach this material.

The first thing that came to my mind when asked to do this assignment was "Teacher as a Detective." I have always thought of teaching as a mystery. No two years are ever the same! Teachers are always placed into classrooms that they have no clue about, especially the students. Also they are constantly looking back on their work and using this to help them base their decisions on what strategies they will try next. This is also like what detectives do. They are constantly looking back at their clues and deciding what new kinds of things they should be looking for to help them find the answers to what they need. I believe teachers would be great detectives and detectives would be great teachers. They both go through some of the same types of processes and use some of the same strategies to do their work.

Appendix C

Case Writing Protocol

Case Writing Protocol

Case Writing: Dilemmas from Teachers' Experience

Teachers will use a real or imaginary classroom situation as the basis for developing the case. Teachers may choose to enhance a real situation with imaginary details. The written case should include a clear description of the dilemma or challenge. The case may include any or all of the following components:

1. Description of the teacher
2. Teacher's background and/or experiences
3. Description of the classroom, school, or community
4. Description of the students
5. Teacher's feeling and intentions
6. Students' feeling and intentions
7. Actual or imaginary dialogue
8. Description of other relevant parties (e.g., parents, principals, other teachers)

Do not include a solution, outcomes, or morals in the case. Teachers may use as many or as few of these components as they like, teachers may arrange them in any order. There is no correct way to write an open case.

* Teachers can use the same components for "writing a closed case", but in a closed case teachers can include the outcomes (How did the solutions work?) and morals that can be drawn from the case.

Appendix D

Written Cases for Case-based Pedagogy Learning

Written Cases for Case-based Pedagogy Learning

Case 1: Too Many Questions, Too Little Time

Bongkoch is an elementary teacher with ten years of experience. She loves to teach little children. After graduation, she decided to teach elementary school. From her experience Bongkoch has noticed that, Thai children are not very active when it comes to asking questions. She realizes that this is partly do to their culture where Thai children are taught to always listen to adults. However, Bongkoch knows that asking questions is a necessary part of learning science. It is also an important characteristic of scientists.

Fifth grade teacher “Bongkoch” was eager to try the new science inquiry methods, she had learned about in a recent professional development workshop. She knew that an important aspect of inquiry was to incorporate more open-ended questions into lessons by asking children questions that potentially had more than one correct answer or questions that allowed students to explain their thinking. As Bongkoch implemented these new questioning techniques, she began to see that the children had more to contribute to the class than she had previously assumed. However, she also came to realize that asking good questions was only one piece of the classroom communication when using an inquiry approach to science teaching.

Bongkoch’s class of forty five students included children with a range of understandings of science content and diverse communication skills. During the 2006 school year, the teachers in Bongkoch’s school had been focusing on engaging all students in hands-on, minds-on activities and in class discussions. The teachers had participated in professional development workshops about the use of questioning strategies with inquiry-based science.

Bongkoch decided to put her new knowledge of questioning strategies into practice during her unit on weather. Throughout the weather unit she tried to ask children questions that had more than one correct answer and encouraged them to explain their thinking. As she implemented these new questioning techniques, she saw that children had more to contribute to the class than ever before. They had lots of ideas about weather and were able to make connections to other topics they had been studying. However, Bongkoch soon came to realize that asking good questions brought other, unanticipated challenges into sharper focus. When students were invited to share their own ideas, Bongkoch listened carefully to what they were saying and thought quickly about ways to respond to their contributions. A particular challenge was finding ways to respond to students' questions in ways that were respectful and encouraging — this was harder than Bongkoch initially expected. The other unanticipated challenge was getting the students to listen to each other. The students were used to the teacher being the authority in the classroom and were not accustomed to listening to their peers. They were also sometimes impatient with their peers who were less articulate, and they occasionally ridiculed each other. Bongkoch was comforted to discover that her fellow teachers were struggling with many of the same issues, but no one seemed to have a ready solution.

During one particular lesson, Bongkoch decided to have students work cooperatively in groups to create diagrams of the water cycle. She hoped they would work together to discuss and synthesize what they had learned about the role of the water cycle in weather. When all of groups had finished their water cycle diagrams, Bongkoch asked them to share with the class. Tweesak proudly showed their picture pointing and explaining that rain comes from the sun. Bongkoch asked the group

"Where does the rain from?"

"Rain comes from the sun" replied Tweesak

Bongkoch thought to herself, "I am sure this group has a misconception about the water cycle. I need to elicit their conceptions by asking some probing questions."

"Why do you think that rain comes from the sun? Can you give me an explanation?"

"Umm, because I didn't see the sun when it was raining. I think that rain comes from the sun. When the rain stops, the sun appears again." Tweesak explained.

"Do you all agree with the point Tweesak is making?" Bongkoch asked. Timidly seven of the students raised their hands. "Does anyone have another explanation about why the sun seems to disappear when it is raining?"

Keawta volunteered, “The sun disappears because many dark clouds cover the sky and the sun.”

“How do the clouds form?” asked Bongkoch

Pattama, eager to answer this question, replied “Clouds come from the condensation of vapor.”

Although this was the answer that Bongkoch was secretly hoping for, she continued with her questioning. She wanted to elicit students’ developing conceptions about evaporation.

“How does the vapor form?” Bongkoch asked

“Through evaporation,” Pattama volunteered.

“Can you explain how water evaporates?” Many groups were eager to explain the process of evaporation.

They raised their hands quickly, hoping that Bongkoch would call on them to answer the question. Instead, Bongkoch called on “Pongpudd” a shy student in one of the groups.

“Pongpudd, can you explain the process of evaporation?” Pongpudd hesitated. Actually, Pongpudd was very shy and had frozen in the past when called on to answer a question for which he had not volunteered. This time was no different. Embarrassed, Pongpudd laid his head down on the desk. Bongkoch was concerned that some students, like Pongpudd, were not paying attention because they were not involved in the discussion. At this point she made an on-the-spot decision to engage students in small group discussion. She asked them to discuss “evaporation” in their small groups

“With the members of your group, I want you to discuss how you came up with your ideas. Where do clouds come from? And how do clouds relate to rain?”

After about ten minutes of small group discussion, Bongkoch pulled the class back together. She continued to focus her question on Pongpudd.

“Can you explain the process of evaporation?” she asked Pongpudd. He hesitated, but this time his friends in the group encourage him to respond.

“The water on the ground is heated by the sun. Heated water becomes vapor. These vapors touch the cool air and become clouds,” explained Pongpudd.

“So what part of this is evaporation?” asked Bongkoch.

“Evaporation is where the heated water becomes vapor,” answered Pongpudd.

“How about the part of the process where vapor touches the cool air and becomes a cloud? What do we call this part of the process?”

“Condensation” answered Veerawan, another student in Pongpudd’s group.

“Good job for Pongpudd’s group. Does any group have a different explanation?”

“Can any group tell me where the rain comes from?” asked Bongkoch.

“It comes from a cloud. When there are many clouds in the sky it will join together by wind and the weight will be so heavy. Then the rain falls down from the cloud,” explained Pattama.

“Does any group have another idea?” asked Bongkoch. Keawta raised her hand and asked,

“Why are dark clouds so dark?”

“What is your idea? Why do you think some clouds are dark? Does anybody have an idea?” asked Bongkoch. Keawta was silent, so

Kamol explained, “Maybe the rainy cloud is too heavy. As it comes near to the ground it carries a lot of dust. This makes the cloud dark.”

“Any other ideas?” when no one else responded, Bongkoch explained

“Kamol’s answer is nearly correct. The rainy clouds are dark because they are too thick, not because of dust. There are many clouds join together and they are very high and vertical. Can anybody guess how the thick cloud becomes so dark?” asked Bongkoch.

“Maybe the thick cloud covers the sun. Sunlight cannot shine through the cloud,” explained Keawta.

“Good Keawta…that is the reason why rainy clouds look dark. Bongkoch glanced at her watch, realizing that there was no more time for science and she had only completed part of her lesson on the water cycle. There would be no time for a demonstration. As self-doubt rose to the surface, Bongkoch wondered if she should have spent so much time on questioning. Wouldn’t it be more efficient just to tell students the correct answers?

Questions for Reflection and Discussion

1. How can Bongkoch involve more students in the discussion without making shy students, like Pongpadd, feel put on the spot?
2. What should a teacher do when students give responses that are not scientifically correct?
3. Asking children to explain their thinking is time consuming. How might a teacher balance the need to cover material with the desire to elicit thinking?
4. How do you help children learn to listen respectfully to each other? How might you respond when children ridicule the answer of a peer or when children become impatient with a student who is less articulate?

Case 2: Between a Rock and a Hard Place: Assessment Dilemmas in Inquiry Science

Last year, Pathumtana Elementary School, a rural elementary school of about 600 students located in Pathumthani province, eliminated science textbooks and adopted module kits for all science classes. The kits were purchased from several vendors and were selected primarily for the quality of their hands-on science experiences, and their emphasis on inquiry. At the beginning of the year, the teachers were eager to use the new kit-based curriculum materials. However, after several months of use, they were still having some doubts as they struggled with several problems that emerged related to assessment. The adoption of inquiry-based modular science kits raised concerns about assessing students' science learning for Rawit and his grade-level colleagues. The teachers considered the background information and assessment suggestions provided with the kits woefully inadequate. At lunchtime their discussion centered on several assessment-related issues with which the teachers were grappling as they used the kits for the first time. Rawit and the other teachers knew that there was no quick and easy solution to their assessment dilemma. Rawit and Priya, both fifth grade teachers, decided to conduct an investigation of their authentic assessment practices, focusing their concerns on student learning.

Later in the week, the fifth grade team meeting was dedicated to an informal discussion of these assessment issues. As the teachers began to share some of their frustrations related to the modular kit assessment, Priya shared her concern with the performance assessment task included in a module on rock classification. The conversation that took place follows:

Priya: I was using the skills checklist that came with the kit. It includes the item "successfully identify igneous, metamorphosis, and sediment rocks." I circulated around my classroom and checked off the groups which were able to classify the three types of rocks. I was not surprised when Udom's group was the first group to accomplish the task. I checked off all the members' name. At the same time, I noticed that Sakdipong, who was sitting in the group next to Udom, was watching Udom's group and copying their ideas for classification. Sakdipong was whispering to the other members of his group telling them the criteria they needed to use to classify the rocks. He soon raised his hand and asked me to check his group. I checked off all the members' names of this group, but had a linger feeling that I wasn't being fair. I wondered whether Sakdipong's group had a true understanding of the characteristics of each type of rock. Should Sakdipong's group receive the same evaluation as Udom's group? Udom' s group was able to complete the task on their own while it seemed that Sakdipong and his peers had simply copied the ideas of the other group.

Janjira: As I see it, each child needs to progress through his or her own level of understanding, and it really doesn't matter whether Sakdipong copied a nearby group. I actually think that we should encourage children to learn from each other. The point is not how he learned to classify the types of rock, but that he did put those rocks in the right group.

Ornuch: Is that really the point? Do we want to create students who just blindly perform tasks without the proper understanding of the concepts that are taking place within that task? I'm not sure Sakdipong and his friends understand as much as Udom's group about the properties of each type of rock. Just because they successfully copied and put the rocks in the correct groups does not mean that they know how to classify rocks on their own.

Janjira: I agree, but can we automatically assume that Udom and his friends understand more just because they completed the activity first? They may have stumbled onto a way to classify the rocks without really understanding much about what they were doing. It is even possible that Sakdipong understands more that Udom after applying what he saw to solving the problem.

Rawit: It seems to me that there is some confusion about what we are trying to assess. The kits do not really provide sufficient teacher background information about the concepts being studied, and I am left wondering whether we are talking about assessing students' understanding of the properties of rocks, their ability to classify them, or both. Ultimately, don't we want students who are not just mindlessly performing tasks but are able to discuss or explain the task intelligently?

Priya: It seems that we want to assess what children can do and what they know. I am frustrated because I don't feel like I am getting at what students have actually learned. The skills checklist that came with the kit is the simplest assessment tool to use. All I have to do is make a copy for each child and check off the skills as I observe them completing them. There are other assessment suggestions in the teachers' guide, such as concept mapping and student-generated questions and answers, but they come with little guidance about what to look for or how to score and evaluate them. I don't know whether the checklist alone is enough to really get a true picture of what the student knows.

Ornuch: Yeah, I know what you mean. I also had some difficulty in knowing how to follow up with some of the students' work. I am not sure when to correct students and when to allow their own personal theories to be documented and shared with the class. I wish the kits provided us with more guidance as to what concepts students should be able to understand. For me, I asked my students to do homework after we learned the composition of rocks. I added a "Let's make your own rocks" to the assessment part. I thought it was a good opportunity for students to use their creativity to think about properties and composition by constructing rocks from clay and other materials. They could bring the constructed rocks to the class to share their ideas with friends. The next day I received a note from a parent with a physics degree expressing concern that my assessment strategies might foster students' misconceptions. Now I'm not sure when to correct students or when to allow their own personal theories to be shared with the class. I wish the kits provide us with more guidance as to what concepts students should be able to understand, and the most effective ways of assessing learning.

Rawit: I see your point, Ornuch. Once you understood students' thinking and the ideas behind their theories, it didn't seem as necessary to focus on misconceptions. What worries me is the teachers who wouldn't even recognize non – scientific theories until that parent's note pointed it out to them. Is the process students go through to investigate something ultimately more important than the actual information being obtained? Once again this boils down to: Are we assessing their understanding of a concept or their ability to perform a certain task?

The lively discussion continued even as the bell rang, bringing the lunchtime grade-level meeting to a close. Priya summed up the group's concerns related to assessment and evaluation of the kits in comparison to materials used in the past:

The consensus seems to be that we need more information. The checklist provides an easy way to score each child but leaves too many unanswered questions. As a grade-level team, we all seem to be struggling with several issues. Although we don't want assessment to stand in the way of a student's inquiry, we need to find a way to get beyond what children do and gain insight into what they understand. Furthermore, we all share Ornuch's concerns about the balance between knowing when to correct students' alternative conceptions while recognizing that these alternative conceptions are necessary steps in the students' progression toward more sophisticated understandings. We all agree on the need to help parents understand hands-on, performance based assessment. So where do we go from here? How do we construct the knowledge needed to develop meaningful science assessments for our students?

Question for Reflection and Discussion

1. When is it appropriate for students to demonstrate what they can do and when is it appropriate for students to demonstrate what they understand?
2. How can teachers help students show what they understand rather than what they can do?
3. Are alternative conceptions a developmental necessity as children progress to more sophisticated understandings? Explain your response.
4. What assumptions about teaching and learning are reflected in the teachers' discussion?
5. Do teachers need to know what children understand? Why?
6. What assumptions about power, stance, and control of learning are implied by the teachers' need to know what children understand or can do?
7. How can a teacher know whether a student has a scientifically ac understanding of a concept?

Appendix E

Modified Lesson Study Protocol

Modified Lesson Study Protocol

A) Teaching and observation (case study teachers): the guided questions for team to conduct observation will be considered:

- Focus on the lesson plan that you selected to be observed, think about the students. "What would you expect your students to do in the objective of the lesson plan?"

- Set the specific questions for this observation that will help you to review the nature of the lesson when the students interact in your teaching.

"What are the questions that you will use to guide the observation of the students in the classroom based on your expectations?"

B) Analyze the lesson plan and revise or redesign lesson plan (case study teachers): the guided questions for team to conduct analysis will be considered:

"What is the effect of the lesson on the students' learning?"

"How can you make this lesson better the next time you teach it?"

C) Meet and reflect on the experience and technique of modified lesson study (case study teachers): the guided questions for team to conduct reflection will be considered:

"How does the technique of this modified lesson study enable you to improve your teaching?"

"Do you like to work with the other teachers in collaboratively designing your lesson plan? Why or why not?

Appendix F

Semistructure Interview: Teacher's Current Teaching and Professional Development Needs

Semistructure Interview: Teacher's Current Teaching and Professional Development Needs

Objective

To explore teacher's existing knowledge about earth science content, current teaching, problem in teaching, and professional development need

Questions

1. What field did you graduate?
2. How many years of your teaching experience? How many years of your science teaching experience?
3. Does your school context (learning media, resource, and communities) enhance learning organization?
4. Do you write lesson plan for every lesson?

(If yes)
- What is the form of your lesson plan?
- How to determine objectives of the lesson?
- What is the teaching technique often using for science lesson?
- What is the learning media often using in science lesson?
- What is the evaluation techniques for science lesson?

(If No)
- How do you plan what will the students learn?
- How do you plan about the media and evaluation technique to use?

5. Can you describe the weather concepts that you will teach for next semester? (the interviewer can extend the questions to other weather topics that are related)
6. Can you describe the geology concepts that you will teach for next semester? (the interviewer can extend the questions to other geology topics that are related)
7. What is the challenge or problem for your teaching in next semester? Why?

Appendix G

Semistructural Journal Protocol:
Growth of Teachers in Earth Science Teaching

Semistructural Journal Protocol:
Growth of Teachers in Earth Science Teaching

The following questions are distributed to teachers in each week of participating in the reflective, inquiry-based professional development

Week 1: Before workshop
- What is your intension of science teaching to be relevant with Thai educational reform?

Week 2: During workshop
- What did you learn about science content knowledge?
- What did you learn about learning organization?

Week 3: Before lesson study
- How do you prepare science content for lesson study?
- How do you prepare yourself and your students for lesson study?
- How are your confident for inquiry teaching in this semester?

Week 4: After lesson study
- What do you know more on science content in your lesson?
- Do you prefer 5E inquiry instruction which you are designing?
- What do you want to improve your lesson?
- What are the advantage and disadvantage of collaborative working in lesson study?

Week 5: Experience from professional development
- How do you organize learning process for all students?
- What technique do you bring to support inquiry?
- What is the advantage and disadvantage of 5E inquiry instruction?
- What is the problem found on 5E inquiry instruction?
- Will you teach by inquiry-based for next semester? How?

Appendix H

The Science Teacher Inquiry Rubric

The Science Teacher Inquiry Rubric

Table H1 The science teacher inquiry rubric

	Learner-centered	⟵	⟶		Teacher-centered
	4	3	2	1	0
CATEGORY 1: Learners are engaged by scientifically oriented questions.					
1. Teacher provides an opportunity for learners to engage with a scientifically oriented question.	Learner is prompted to formulate own questions or hypothesis to be tested.	Teacher suggests topic areas or provides samples to help learners formulate own questions or hypothesis	Teacher offers learners lists of questions or hypotheses from which to select	Teacher provides learners with specific stated (or implied) questions or hypotheses to be investigated	No evidence observed
CATEGORY 2: Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions					
2. Teacher engages learners in planning investigations to gather evidence in response to questions.	Learners develop procedures and protocols to independently plan and conduct a full investigation.	Teacher encourages learners to plan and conduct a full investigation, providing spport and scaffolding with making decisions.	Teacher provides guidelines for learners to planned conduct part of an investigation. Some choices are made by the learners.	Teacher provides the procedures and protocols for the students to conduct the investigation.	No evidence observed
3. Teacher helps learners give priority to evidence, which allows them to draw conclusions and/or develop and evaluate explanations that address scientifically oriented questions.	Teacher directs learners to collect certain data or provides only a portion of needed data. Teacher often provides protocols for data collection.	Teacher provides data and asks learners to analyze.	Teacher provides data and gives specific direction on how data is to be analyzed.	Teacher provides data and gives specific direction on how data is to be analyzed.	No evidence observed.
CATEGORY 3: Learners formulate conclusions and/or explanations from evidence to address scientifically oriented questions.					
4. Learners formulate conclusions and/or explanations from evidence to address scientifically oriented questions.	Learner is prompted to analyze evidence (often in the form of data) and formulate own conclusions/ explanations.	Teacher prompts learners to think about how analyzed evidence leads to conclusions/ explanations but does not cite specific evidence.	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to draw conclusions and/or formulate explanations.	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to lead learners to predetermined correct conclusion/ explanation (verification).	No evidence observed.

Table H1 (Continued)

	Learner-centered 4	3	2	1	Teacher-centered 0
CATEGORY 4: Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.					
5. Learners evaluate their conclusions and/or explanations in light of alternative conclusions/ explanations, particularly those reflecting scientific understanding.	Learner is prompted to examine other resources and make connections and/or explanations independently.	Teacher provides resources to relevant scientific knowledge that may help identify alternative conclusions and/or explanations. Teacher may or may not direct learners to examine these resources.	Teacher does not provide resources to relevant scientific knowledge to help learners formulate alternative conclusions and/or explanations. Instead, teacher identifies related scientific knowledge that could lead to such alternatives or suggests possible connections to such alternatives.	Teacher explicitly states specific connections to alternative conclusions and/or explanations but does not provide resources.	No evidence observed.
CATEGORY 5: Learners communicate and justify their proposed conclusions and/or explanations					
6. Learners communicate and justify their proposed explanations.	Learners specify content and layout to be used to communicate and justify their conclusions and explanations.	Teacher talks about how to improve communication but does not suggest content or layout.	Teacher provides possible content to include and/or layout that might be used.	Teacher specifies content and/or layout to be used.	No evidence observed.

Source: NRC ,2000; Beerer and Bodzin, 2004)

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