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NAME: Miss Benjawan Hanpipat

THIS THESIS HAS BEEN ACCEPTED BY

.... **THESIS ADVISOR**

(Professor Vantipa Roadrangka, Ph.D., Ed.D.)

.... **THESIS CO-ADVISOR**

(Associate Professor Bancha Panacharoensaward, Dr.Ing.)

.... **THESIS CO-ADVISOR**

(Professor Gaalen Erickson, Ph.D.)

.... **DEPARTMENT HEAD**

(Assistant Professor Sudarat Sarnswang, Ph.D.)

APPROVED BY THE GRADUATE SCHOOL ON ....

.... **DEAN**

(Associate Professor Gunjana Theeragool, D.Agr.)

THESIS

ENHANCING THAI GEOLOGY TEACHERS' TEACHING PRACTICES USING THE COLLABORATIVE ACTION RESEARCH WITH A FOCUS ON INTEGRATED CURRICULUM

BENJAWAN HANPIPAT

A Thesis Submitted in Partial Fulfillment of
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This research aims to investigate 1) current Geology teachers' teaching practices and 2) changes in their teaching practices after participating in a collaborative research project that involved them using an integrated curriculum. The study was divided into two phases. The first phase examined the current teaching practices of three upper secondary Geology teachers. Data collection was conducted through classroom observations, interviews, and examples of the individual teacher's tools. The second phase involved the creation of a collaborative action research (CAR) group and meetings which the three participants attended and learned ways to improve their teaching practices. The teachers designed lesson plans individually and collectively according to an integrated curriculum. The implementation of these lesson plans was observed by the researcher and both parties reflected upon them through post-class interviews. The three case studies of the study were based upon the teachers' situations and designed to gather as much understanding of each individual's teaching practices. The data gathered from the multiple resources was inductively analyzed and used to build categories and themes to explain the teachers' situations. Cross-case analysis was used to seek commonalities and differences between the findings for each subject in order to provide understanding of how each teacher's situation affected the results.

The findings in the first phase addressed the situation in which the teachers generally used the lecture-based format of lesson design and teacher-lead discussions for classroom interaction and were very unlikely to use hands-on activities. The study showed that the reasons for these varied in each of the three situations. They involved their individual beliefs in what was the most appropriate way to teach Geology, time constraints due to scheduling or school activities, the extensive amount of content that needed to be covered, and the stress of making sure their students do well on national examinations. The first phase dealt with the problems teachers have with using an integrated curriculum such as non-availability of school facilities. The study showed that the use of an integrated curriculum is likely one that is presented across disciplines rather than within science disciplines. The second phase showed that when teachers and the researcher work together to develop an integrated curriculum and implement it in their classrooms, the teachers tended to change their practices and focus on more hands-on activities either through demonstrations or experiments. To help their students make connections between concepts the teachers used diverse types of materials such as models to represent Geological processes and reading sheets, things they did not do previously. The study showed that the CAR group meetings gave the teachers the opportunity to learn from each other, but as well and that time constraints and their own personal understanding of what an integrated curriculum is can impede its implementation.

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Benjawan Hanpipat
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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (CONTINUED)

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

In recent years, there has been an urgent call for education reform in Thailand and as a result there are presently several sets of guidelines in place for improving students' learning, particularly in the area of scientific literacy in primary and secondary schools: The National Education Act B.E. 2542 (ONEC, 1999), The Basic Curriculum B.E. 2544 (MOE, 2002), The National Science Curriculum Standards B.E. 2544 (IPST, 2002), along with documents from IPST all supported this call for reform. As a result of this reform of education in Thailand, Geology in the National Science Curriculum Standards (IPST, 2002) for the upper secondary levels was introduced as a new content area for all students. Grouped separately into each strand, geological content is strand 6 in these standards and it emphasizes more intensive knowledge and covers broader topics than those in the past. Many new topics introduced in the strand involve geological phenomena, including earthquakes and volcanoes, continental drift, and geological history all of which had not been covered in the last curriculum.

A large body of literature has been created that addresses the interrelationships between related science content found in biology, physics and chemistry with the content found in Geology (Inter-Union Commission on the Teaching of Science, 1968; Orion *et al.*, 1999a, 1999b; Gobert, 2000; King and Kennett, 2002a, 2002b; Revetta and Das, 2002; Dodick and Orion, 2003b; Libarkin *et al*., 2005; IPST, 2005a). As a result, the teaching and learning of Geology in the upper secondary levels is likely to be presented in an integrated form in accordance with the National Education Act B.E. 2542 (1999). Section 24 states that the learning process should involve an integration of all subjects, integrity, values, and attributes. Thus the Basic Education Curriculum B.E. 2544 (MOE, 2002) addressed an attempt to integrate the various forms or methods of teaching and learning. Such integration should integrate all subjects within the same subject group. Integrated instruction is an effective teaching method that uses an interrelationship of several subjects' content rather than fragmented content from separate subjects. As in the real world, most problems and experiences in our lives are interdisciplinary in nature rather than isolated. We use multiple skills and knowledge to learn from these experiences, and to solve everyday problems (Frazee and Rudnitski, 1995; Czerniak *et al.*, 1999). There has always been a relationship between integration and education, but there has not always been agreement on the definition of integration or the form it should take in curriculums (Pursova, 1984; Fogarty, 1991; Frazee and Rudnitski, 1995; Drake and Burns, 2004). Much literature has stated that an integrated curriculum will help students to have a more meaningful learning experience within real world situations (Lambert, 2006) and improve students' learning in all domains, cognitive (Green, 1991; McComas and Wang, 1998; Meier, Nicol, and Cobbs, 1999); affective, (Berlin and Hillen, 1994; McComas and Wang, 1998; Revetta and Das, 2002); and their process skills (Berlin and Hillen, 1994).

Changes in the National Science Curriculum Standards B.E. 2544 (IPST, 2002) have also affected the teaching and learning of Geology. These changes greatly affected Geology teachers in the upper secondary levels who had never taught this content to science students before. Most schools do not have any Earth science specialists or teachers with degrees in Earth science because most science teachers at those levels have backgrounds in biology, chemistry, physics, or general science and are then simply asked as science teachers to add Geology to their teaching assignment, despite their lack of Geology knowledge and training in that area (Hanpipat and Roadrangka, in press). This type of situation occurred in England and Wales as well when there was a similar shift in their science curriculum (King, 1993, 2008). These teachers rarely proved effective at teaching geology since they had inadequate background knowledge or pedagogical knowledge related to Geology (Russell, Qualter, and McGuigan, 1995 cited in King, 2001; Abd-El-Khalick and BouJaoude, 1997). Also, some teachers had no science teaching training at all as well as lacking training in the Earth sciences (Dineley, 1990). This is a major problem as teachers are teaching Geology with insufficient content and pedagogical knowledge (Magrood-In and Yutakom, 2007). Educational reform arose as a result of the reforms efforts to maximize students' learning capabilities and self-development but to accomplish this goal the quality of teachers implementing these reforms is very important to their success. The current reform effort requires a change of teacher practices from simply transmitting knowledge to their students, to helping the students develop their own conceptions while taking into account the students' thinking. Teachers must change from simply being technicians to being constructivist teachers. Learner centered schools, therefore, require a new paradigm for professional development. Consequently, there is no question that professional development is an essential component which is needed to improve content and pedagogical knowledge for teachers of Geology.

In Thailand, the Institute for the Promotion of the Teaching Science and Technology (IPST) is the main organization responsible for the promotion of science, mathematics, and technology, and is responsible for teacher professional development education and thus provides intensive in-service training for science, mathematics, and technology teachers (Pillay, 2002). But the training has likely followed a top-down approach where experts just transmitted good teaching methods to teachers without attention to the teachers' background knowledge or their teaching situation (Kember and McKay, 1996). Traditional professional development has emphasized the individual development of knowledge, skills, and strategies, with no attention to the school setting, professional networks, or the building of a collective learning community. Furthermore, the way teachers have learned is from "experts" teaching-by-telling, more than learning from the teachers' themselves (Loucks-Horsley, 1995). In contrast, true professional development should use a bottom-up approach where professional growth is derived from the teachers' themselves (Pedretti and Hodson, 1995). Teachers should shift their roles from receivers to owners of their classroom practices (Cochran-Smith and Lytle, 1990; Little, 1993; Bell and Gilbert, 1994; Lewis, 2002; Maldonado, 2002). The shift of teacher responsibility corresponds with the educational reform in Thailand in the form of the National Education Act B.E. 2542. Teachers can develop their own teaching and learning activities, instructional materials, content, and time frames. School based curriculum is now more flexible and dependent on local situations. Thus, the teacher is the most important person who takes responsibility to develop his/her instruction methods as they relate to their local situation (Cochran-Smith and Lytle, 1990; Little, 1993; Bell and Gilbert, 1994; Loucks-Horsley, 1995; Liebermen, 1995; Black, 1996; Maldonado, 2002).

The National Education Act B.E. 2542 in section 30, stresses that instructors should be encouraged to carry out research to develop suitable learning for learners at different levels of education. Teachers should intend to perform action research not only to study and solve problems with their own practices (MOE, 2002), but to improve their teaching and to develop professional knowledge and skills in their careers (IPST, 2002). In essence, action research has become increasingly acknowledged as professional development to improve teachers' practices, their understanding of those practices, the situations related to those practices and their students' learning (Tabachnick and Zeichner, 1999). By taking into account teachers' knowledge, their sense of empowerment and the ownership of their learning and the uniqueness of school contexts, it assures that the growth of teachers' professionalism is constructed from themselves as the practitioners and not from outsiders looking in (Oja and Smulyan, 1989; Cochran-Smith and Lytle, 1990; Hargreaves, 1994; Mcniff and Whitehead, 2006; Stringer, 2007). Particularly, collaborative action research (CAR) provides an opportunity for teachers to share their experiences and knowledge and work collaboratively with their colleagues in the same field and with university researchers (Feldman, 1996; Capobianco, 2002; Christensen, 2005). They are able to generate new knowledge and gain better understandings of their educational situations. The CAR is a powerful type of action research that can provide participating teachers with a powerful advantage and break the isolation between teachers in different fields or departments in the workplace (Carr and Kemmis, 1986 cited in Feldman, 1993).

This study draws upon the interpretive research which concentrates most on understanding the three teachers participating in the CAR group. Three teachers, one researcher and one university science educator all had their own distinct roles in the research. The teachers' role was to examine their teaching practices and then find ways to implement an integrated curriculum into their practices. The teachers worked collaboratively with others in the CAR group to build their collective learning and to try and improve their practices through four stages; planning, acting, observing and reflecting; whereas the researcher was simply a facilitator who helped the teachers with giving suggestions, or advises for teachers' lesson plan, being a good listeners for teachers' feedback, and questioning them to elicit their' ideas and understanding of their practices. Follow-up occurred with each teacher by asking them to provide detailed descriptions of how they improved their classroom practices or what they learned from the CAR group. Multiple data collection methods included; interviews, teachers' reflective journals, classroom observations, the researchers' journals, and other document artifacts. These were used to provide a variety of information regarding the teachers' perspectives, classroom practices, and reflections when being a part of a collaborative action research group. The researcher analyzed all the data using inductive analysis to categorize emerging issues into themes which were then explained in each case study. Case and cross-case analysis was used to compare and contrast the findings among the different case studies in order to build a holistic perspective of the teachers' practices.

Research Purposes

In the light of the call for the reform of teaching and learning practices along with an emphasis on integration and a transformation of the science curriculum in Thailand, Geology content was introduced to students and teachers in the upper secondary levels. This study aims to examine current Geology teachers' teaching practices in schools and to understand the changes in their practices and examine teachers' learning as they develop an integrated curriculum while being engaged in collaboration with other teachers, the researcher, and the science educator in the collaborative action research (CAR) group.

Research Questions

The research answered the following questions:

1. How do Geology teachers' actual teaching practices compare to the integrated curriculum's suggested teaching practices?

2. How do Geology teachers change their teaching practices after participating in the collaborative action research group (CAR)?

Anticipated Outcomes

1. This study might be useful for other teachers engaged in collaborative action research in order for them to understand and to improve their own teaching practices by ignoring teacher isolation. The collaboration of teachers should not only occur in science departments but also amongst those in other departments or among all the stakeholders like administrators and should be seen as an opportunity to promote professional growth in knowledge as well as pedagogy in the classroom.

2. This study could be a guideline for other teachers to recognize the importance of integration in their discipline and create the opportunity to use integration as a teaching practice. When involved in conducting action research, teachers should be enabled to generate their own problems, systematically collect and analyze data and in this way they may ultimately end up figuring out and solving their own problems.

Delimitations of the Study

This study was conducted using three Geology teachers teaching in the upper secondary levels from 3 public schools under the Bangkok Education Service, Area 2. All participants taught Geology in both semesters of the 2008 academic year. All of them were chosen from the voluntarily participation addressed in the researchers' questionnaires in the pilot study. The scope of the Geology concepts in this study were specific to the upper secondary grade levels and consisted of three main topics listed in the National Science Curriculum Standards (IPST, 2002) and the textbook "Earth, Astronomy, and Space for 11th grade students" published by IPST (2001).

1) The Earth and the changing process including two subtopics

1.1) Structure of the Earth

1.2) Geological phenomena including both earthquakes and volcanoes, concepts that relate to the causality and processes of earthquakes and volcanoes erupting and their effects on the Earth's surface, explanations about seismic waves, and regions where earthquakes and volcanoes would most likely occur.

2) Plate tectonics

2.1) Tectonic plates and their movement

2.2) Geological evidence relating to continental drift with regard to the theory, explanation of fractures within the plates, plate boundaries, and mid-ocean ridges.

3) Geological history

3.1) Geological time

3.2) Fossils

3.3) Rocks

Definition of Terms

An Integrated Curriculum in this study is defined as teacher-developed lessons that must have been planned in advance of teaching and learning activities based on student-centered learning processes throughout the semester. The lessons represented the integration content knowledge of geology with other related science content knowledge. Lessons consisted of; the purpose of the lesson, the content knowledge, teaching and learning activities, use of teaching and learning materials, and assessment and evaluation techniques. All of these lessons were analyzed as a means to understand the teachers' perspectives about integration in Geology.

Teachers' Teaching Practices are defined as the processes of teaching and learning that are used in the classroom by the teacher and these can include; the teaching and learning processes, the use of teaching and learning materials, assessment and evaluation procedures, and the use of an integrated curriculum. Considering these aspects, the researcher collected data from the teachers' planning, classroom activities, the interaction between teachers and students, classroom organization, implementing teaching and learning resources and students' assessment. Integrated science teaching was examined through classroom observations and interviews with teachers after teaching.

The Collaborative Action Research Group (CAR) is defined as a group of voluntary Geology teachers who work collaboratively together within the group along with one researcher and one science educator. To conduct action research, teachers systematically discuss ways to plan, act, observe and reflect upon their teaching of Geology in order to improve their practices. The CAR group meetings took place monthly and were an opportunity for the participants to share experiences, contribute valuable knowledge, or reflect upon things that happened in the classroom. In addition to being a part of the CAR group and working with the teachers in that situation, one researcher also worked with individual teachers in their own schools as well.

Summary and Preview

The first chapter mainly presents the background regarding Geology education in Thailand and the idea that this study concentrates on promoting the professional growth of teachers by having them participate in a collaborative action research group so they can perhaps change their teaching practices and utilize an integrated curriculum. The research's purposes and the study's questions are provided along with anticipated outcomes, a delimitation of the study, and definitions of the terms.

Chapter Two focuses on the Geology teachers from upper secondary levels who develop an integrated curriculum and how their practices are influenced through conducting collaborative action research (CAR). It is essential to review the state of Geological education in Thailand, the importance of an integrated curriculum, the status of professional development in Thailand and the notion of collaborative action research.

Chapter Three discusses the framework of the qualitative study and the interpretive research. The framework of the study is described using the specific context of the schools, students, teachers as well as the methods of collecting data such as observation, interviews, group meetings, or document analysis. Data analysis is introduced as the framework for interpreting data. The chapter ends up with a description to develop trustworthiness and ethical issue in this study.

Chapter Four contains the findings from the three cases of the individual participants. Each case presents the practices of the teachers in relation to the research questions. At the beginning of each case, the context of the teacher such as her educational background, teaching experience, classroom settings, and context of the students are described. The investigation of the teachers' teaching practices covers four main aspects, teaching and learning processes, the use of teaching and learning materials, assessment and evaluation procedures, and using an integrated curriculum. The findings on how teachers improved their use of the integrated curriculum and their practices when participating in the CAR are also described in this chapter. The evidence gathered from the CAR group meetings is included to demonstrate the collective learning from the group. The teachers and their practices are described using several themes that emerged after studying the empirical data in their natural setting.

Chapters Five describes the trends that occurred in the three case studies in their commonalities and differences. The discussion is separated into the commonalities and differences as they relate to the two research questions. The themes of the teachers' teaching practices are supported by numerous studies and literature in this chapter.

In chapter Six, the conclusions of the previous chapters are described. At the start a brief review of the research procedures for both phases are described and are show in a graphic figure. Conclusions made from both research questions are provided along with related implications for other school practitioners in any situation. The chapter ends with suggestions for further research.

CHAPTER II

LITERATURE REVIEW

Introduction

This chapter reviews the focus of Geology teachers in developing an integrated curriculum by conducting collaborative action research. This section will therefore explain the ideas of all the aspects of the study. The first section of this chapter introduces the concept of National Education Reform in Thailand which generated the curriculum changes regarding Geological education. The second section of this chapter will discuss the Geology content that is now covered in the upper secondary levels and illustrate some of the relationships between its content and the content found in other areas of science. This leads to the notion of an integrated curriculum and it and its characteristics is discussed in the third section of this chapter as well its benefits and challenges when implementing it. The fourth section addresses various studies done regarding Geology teachers' teaching practices when they faced this new reform of having Geology now included in the science curriculum. The teachers who were now responsible to add Geological content to their teaching loads, especially those who were now "deemed" the Geology teachers were greatly affected by this new addition to the curriculum and thus it was necessary to do some professional development to support these teachers. The fourth section provides a description of the typical forms of teacher professional development in Thailand. The call for reform in traditional professional development methods is found in this section as well as a description of the new action research approach to professional development.

National Education Reform

Educational reform was called for in Thailand in 1999 and it prompted a need for the "re-examination of human resources development to develop a nation of wealth, stability and dignity, and a full-fledged member of the global community" (Office of the Education Council (OEC), 1999). Thailand recognized this urgent need by acting through the Office of the National Education Commission (ONEC) by establishing the National Education Act B.E. 2542 (1999) as the new framework for Thai education. The three key aspects of the Act are (ONEC, 1999; Watanachai, 2002):

a) Learning reform - that is, attaching highest importance to learner-oriented education which allows students to develop at their own pace and within their individual potential. The Act represents an exceptional break from traditional Thai educational norms such as lecturing and rote learning and instead sets the foundation for a more creative, questioning approach to studying.

b) Administrative reform - the Act also sets out to decentralize finance and administration, giving individual teachers and institutions more freedom to set curricula to increase efficiency in the utilization of resources and investment for educational purposes transforming the central ministry to local education authorities and to school boards.

c) Equity and quality – Compulsory education is extended from six to nine years and a twelve-year basic education for all children. In regards to the quality of education, there are curricula reform for basic education, restructuring and reform of teachers' education and teachers' career development, and quality assurance system.

The National Education Act B.E. 2542 (1999) was the guideline for the revision of the National Science Curriculum Standard B.E. 2544 (NSCS) (2002) in alignment with the three reform characteristics described above. Geology went through a very drastic transformation as a result of the reforms and the manner in which it is now presented in the NSCS. The following section describes the changes that occurred regarding the teaching of Geology in Thailand both before and after the revisions took place in the NSCS.

Geological Education in Thailand

Recent reforms challenge Geology teachers in deciding what and how to teach

Educational reform was primarily motivated by a call for changes to the 1981 Science curriculum that was still being taught. In 2002, the National Science Curriculum Standards B.E. 2544 (IPST, 2002) was beginning to be implemented in Thailand and there were major changes to the teaching of Geology especially in the secondary levels. The changes included the scope and sequence of the topics as well as the content to be covered in each area. These changes are described below:

Changes in coordination and sequence

In the former science curriculum, the Lower Secondary Grades' Curriculum B.E. 2521 (Revised B.E. 2533) (MOE, 1992a) mandated that all junior high school students, grade seven to nine, were required to learn some Geology. The Geology content, which was commonly taught at the eighth grade, was comprised of topics that covered the structure of the Earth, the changing of the Earth's surfaces, and its natural resources. In the Upper Secondary Grades' Curriculum B.E. 2524 (Revised B.E. 2533; MOE, 1992b), the content of science was organized into two structures that corresponded with the students' programs. Structure One was for students in the non-science-oriented programs, Art, Humanities and the Vocational study program who took the fundamental science courses: physical and biological science; Structure Two was for students in the science-oriented program. Science and Mathematics who studied advance science courses: physics, chemistry, biology and basic biological technology. All the content of both structures is presented in Table 2.1.

Table 2.1 Topics of the Study in Science Curriculum in the Upper Secondary Levels

Structure One	**Structure Two**
Core Course	Core Course
Physical Science	Physics 421
Unit 1: *Sunlight and Energy*	Chemistry 431
Unit 2: *World of Vision*	Biology 441
Unit 3: *Synthetic Substance*	
Unit 4: *Electricity and Facilities*	
Unit 5: *Sound in Every Day Life*	
Unit 6: *Invisible Rays*	
Unit 7: *Astronomy*	
Unit 8: *Natural Resources and Industry*	
-Importance of natural resources and industry	
-Soil composition, pottery industry, Making simple pottery, Properties of glass, Glass making technology, Making simple glass, and Soil preservation	
-Mineral mining, Properties of metal and non-metal minerals, gemstones, fossil fuels, and Preservation of minerals	
-Forrest, Making paper, and Forrest preservation	
-Water and sea, Identifying composition of the sea, and Water preservation	
Course 9: *Colorful Vision*	
Biological Science	
Unit 1: Food and Nutrition	
Unit 2: Medicine and Life	
Unit 3: Genetic Heritage	
Unit 4: Human Body	

Table 2.1 (Continued)

Structure One	Structure Two
	Elective Course
Unit 5: Life and Evolution	Physics 021-025
	Chemistry 031-035
Elective Course	Biology 041-045
Two other topics from the core courses	Fundamental Tissue Culturing 046
	Fundamental Biological Technology 047

As the structure of the content in the upper secondary grade levels shows that some Geology content was distinctly Geological but just a small compulsory part of the curriculum. For example in Topic 8: *Natural Resources and Industry* which studied soil composition as the important ingredient in the pottery industry, Soil and Mineral Preservation. At the lower secondary levels, Geology content in the upper grade levels was not explicitly distinct instead the content was blurred with other specific knowledge in the other sciences in real-life application. Non-science students were to study core courses that cover two topics each semester and two other topics of an elective course each academic year. Only non science-oriented students (Structure One) were given the opportunity to study some Geology content. In contrast, students in the science-oriented program (Structure Two) studied physics, chemistry, and biology and Geology was not included in the content to be studied in the upper secondary grade levels at all.

The new reformed National Science Curriculum Standards B.E. 2544 (IPST, 2002) was first introduced to schools in Thailand in 2001. The Institute for the Promotion of Teaching Science and Technology (IPST) launched this document in response to the National Education Act (1999) and the Basic Education Curriculum (2001). The NSCS is a practical guideline for developing school science programs. In correspondence with educational reform in Thailand, the NSCS adopted as its focus the idea of student-centered learning which puts greater emphasis on constructivist teaching and learning. The document lists a wide range of teaching methods, hands-on activities, teaching and learning resources and useful assessment techniques such as performance assessment or the use of portfolios. This document outlines the scope and coordination (sequence) of the content as a resource for teachers to organize the science courses in grades 1-12. The content of science in the NSCS is organized into eight sub-strands: biology, physics, chemistry, geology, astronomy, and the nature of science. The sub-strands are: Sub-strand 1: Living Things and Living Processes; Sub-strand 2: Life and the Environment; Sub-strand 3: Matter and its Properties; Sub-strand 4: Forces and Motion; Sub-strand 5: Energy; Sub-strand 6: Processes that Shape the Earth; Sub-strand 7: Astronomy and Space; and Sub-strand 8: Nature of Science and Technology.

The NSCS mandates that all students in each stage: Stage 1: (grades 1-3); Stage 2 (grades 4-6); Stage 3 (grades 7-9); and Stage 4 (grades 10-12), are required to complete all eight sub-strands in each stage. The standards extensively outline the scope of the Geology content to be covered in each stage and each school has to organize its school-based science curriculum in an effort to fulfill this mandate. The higher the stage the students are in, the more complicated the Geology concepts they study and thus it is a spiral curriculum as content is not listed by grade but by stage level which is representing three different grades. The teachers thus have three grades in which to cover all the content in the relevant stage. Unlike the former Upper Science Curriculum, all students in the upper secondary grade levels (Level 3 and 4) both science-oriented and non science-oriented program are now mandated to study Geology because the new reforms recognized that students need to learn multiple areas of science throughout their time in secondary education.

Changes in the scope of content

In the area of the Geology content for the upper secondary levels, the new NSCS includes a number of new content areas as compared to the former science curriculum. One sub-strand is devoted to topics in Geology, *Processes that Shape the Earth*. According to IPST textbook Earth, Astronomy and Space (IPST, 2004b), Geology content is organized into three chapters: Chapter One: the Earth’s structure, earthquakes and volcanoes, Chapter Two: plate tectonics and plate movement, evidence and geological information; and Chapter Three: geologic time periods, fossil records, and rock stratification. This textbook combines contents in both sub-strand 6 and 7. Seventy-nine out of 132 pages of the textbook is devoted to Geological content and is found in the first half of the book while the second half discusses astronomy and space. It is clear then that there are numerous Geological topics included in the new upper secondary grade level science curriculum. Additionally, up-to-date content are included in the textbook such as the Tsunami devastation in South East Asia in 2004. Table 2.2 describes the changes in the Geology content.

Table 2.2 Changes in Scope, Sequence and Coordination between the Former Science Curriculum and the NSCS Regarding Geology Content

Curriculum	Target Students	Arrangement in Curriculum	Content areas
Lower Secondary Curriculum B.E. 2521 (Revised B.E. 2533), 1992	For all junior high students	In general science for grade 8	Limited content areas
Upper Secondary Curriculum B.E. 2524 (Revised B.E. 2533), 1992	For non-science senior high students	As one course in physical and biological science	Application in everyday life, e.g. Soil under subtopic of natural resources and industry
National Science Curriculum Standard, 2002	For all students in every levels	As one of eight sub-standards Sub-strand 6: Processes that Shape the Earth	Including several new content areas, e.g. earthquakes, volcanoes, plate tectonics, Earth history.

The structure of the science curriculum for students in many countries such as Israel, England, Wales, and America had already adopted this pattern of science content. In the past the belief that studying the traditional three sciences was much more important and superior than learning of Geology or Earth science (Orion *et al.*, 1999a, 1999b). This limited the chances for students to learn Geology unless curriculums moved away from the three traditional sciences as in the previous curriculum. The content also appeared to lack up-to-date knowledge and did not cover the whole area of geology.

It is obvious that these changes to the Geology content in the Science curriculum had a great affect on the individuals that would have to implement these changes in the classroom. The following section reviews studies done regarding Geology teachers in many countries in terms of their educational background, current practices, and any problems that occurred in the school after recent changes in the curriculum.

Previous Research on the Teaching Practices of Geology

Terminology

The NSCS greatly enhanced the status of Earth science education including "Geology, hydrology, oceanography, meteorology, climatology, and even astronomy" (Orion and Ault, 2007, pp.655). King (2008) referred to the term "geo-science" as being narrow to specific with the exclusion of the atmosphere and oceans, geomorphology and soils. In this study, the research prefers to use the term "Geology" as the specific concept that the upper secondary grade levels concentrate upon.

Current Geology Teachers' Backgrounds

King (2008) studied the background of geo-science teachers in several countries. In Japan, Korea and Taiwan, geo-science is taught by geo-science specialists and general science teachers. While in New Zealand and South Africa, it is taught by general science teachers. In the United Kingdom it is taught by chemistry specialists because in the National Science Curriculum Geological content is aligned with the chemistry topics. No Geology specialists were used in teachers 14-16 year olds. The research of teachers' educational backgrounds in Earth science showed that 63 percent of them had no background in Earth science and nineteen percent had never taken a course in Earth science since their own primary or secondary schooling. The remaining percentage had some background in Earth science from university (King, 2001, 2003). Research carried out on Geology teachers in urban public schools in Bangkok, Thailand, particularly in the Bangkok Educational Service, Area 2 by Hanpipat and Roadrangka (in press) found teachers' educational backgrounds varied and they varied in their different fields of study as well. The majority of these teachers had backgrounds in science education, predominantly General Science at the Bachelor's Degree level and some a Master's Degree in Science Teaching. It is noteworthy that none of these teachers had a major science background in Geology from university and the rest had never taken a course related to Geology in university. The lack of specialized Earth science teachers would make it difficult to fully implement the new science curriculum and to achieve its goals (Jimenez-Aleixandre and Puig 1995).

The inadequacy and direction of current teacher production have not corresponded with the new demands of the science curriculum and this has also not supported the implementation of this new curriculum. In the last ten years of graduating new science teachers the demand has outnumbered the supply all over Thailand (Silpabanlaeng, 2005; Silpabanlaeng *et al.*, 2006). This is not just simply due to a falling number of individuals graduating with degrees in Science teaching, but also to the fall in graduates from education in all areas. As a result many teachers are teaching subjects in which their qualifications to not match up and thus are practitioners of "out-of-field teaching". From the pilot study on the educational backgrounds of the science teachers who have been put in charge of teaching Geology it was discovered that not one of those teachers had graduated from the field of Geology. When taking into consideration science teacher production in Thailand from Rajabhat University (formally a teacher training institute) and the faculties of education in the many Thai universities, they have produced graduates only in the four main science disciplines: physics, chemistry, biology, and general science. In 1996, IPST in cooperation with the Ministry of Education and the Commission of Higher Education established a current project that aimed to promote science teacher production by providing scholarships to scientifically and mathematically talented university students. After these sponsored students get their bachelor's degrees in science, they are to take an extra 1-year teacher-training course in a faculty of education (Soydhurum, 2002). However, this project allowed only students majoring in physics, chemistry, biology, mathematics, and computer science to receive these scholarships. Science teacher education institutes and IPST's projects did not Earth science courses as a part of the teaching training program. Thus there is an urgent need for these programs to include courses in the area of Earth science in order for there to be consistency between them and the new Science Curriculum Standards that mandates Geology for all students (Silpabanlaeng, 2005; Silpabanlaeng *et al.*, 2006). When out-of-field teachers take responsibility to teach geology, many of them struggle with different kinds of problems and therefore they need upgrading in their skills and support.

Current Teaching Practices in Geology

There are not many studies regarding the teaching and learning of Geology in the upper secondary levels because Geology has only recently been added to the national curriculums in many countries such as England, Wales, Spain, and Thailand. But once Geology was added to reformed curriculums researchers such as King began to study these areas. King (2001, 2003) studied the teaching practices of Geology teachers in England a decade after the new curriculum was implemented and the study found that a number of Geology teachers were less likely to rely on hands-on activities, experimental labs, and out-of-school field trips. They tended to use more didactic teaching methods such as lectures that put emphasis on remembering facts and content rather than focusing on inquiry based instructions. One of the major reasons for this was the teachers did not have a strong background in Geology as they did not graduate with majors in Geology and thus they did not feel confident when covering the new additional Geology content. They thus had to spend more time learning the content themselves before they could teach it to their students, as well as now having to cover more content that previously, they did not have time to prepare practical activities both in laboratories and field trips. Hacker and Rowe (1997) and Jenkins (2000) noted that revisions of the National Science Curriculum in England and Wales had considerable affect on the teaching practices of Geology teachers. Instead of putting emphasis on the student centered approaches, teachers usually taught students with low level learning skills and allocated a very short time for experimental activities. A study of the current teaching practices of Thai Geology teachers was undertaken using quantitative data from 17 returned questionnaires and the thick-description data gathered from a few participants' interviews, teachers' lesson plans and classroom observations (Hanpipat and Roadrangka, 2009, in press). The findings from the questionnaires showed that teachers put great reliance on the students' textbooks and teachers' manuals as their major sources of content knowledge and activities. Teachers responded that they had implemented a wide range of teaching methods such as lectures, student cooperative learning, student self-studying, and hands-on experiments, but the students rarely had opportunities to take field trips.

Research on Models or Programs for Teaching Geology

Considerable research has addressed numerous activities in an effort to construct an appropriate environment for the teaching and learning of Earth science. Inquiry based teaching is prevalently used in many studies regarding the teaching of geo-science in order to evaluate its effectiveness as compared to the more traditional methods (Chang and Mao, 1999; Chang and Taipei, 2002; Avard, 2009), using computer-assisted instruction (Chang, 2000), and the jigsaw technique (Tewksbury, 1995). These programs put emphasis on a different aspect of student learning: their thinking skills (Orion and Kali, 2005).

In Chang and Mao's research (1999), Taiwanese junior high school students were randomly assigned to take part in the study that examined the efficiency of inquiry-group instruction versus traditional lecture-based teaching. 319 students in received inquiry-based instruction and 293 students received instruction via the traditional approach. The first group was involved in activities that focused on cooperative learning by working having them work on group projects. They gathered data with via discussion and made interpretations before writing their reports and making presentations. The effectiveness of the inquiry instruction was measured by the student performances and their attitudes towards the subject matter. The research findings found that the experimental group had significantly higher achievement scores and better attitudes toward Earth science than those in the group that received instruction via the traditional approach.

Tewksbury (1999) employed hands-on investigative activities, self- and peer-teaching, and group learning to enhance non-science major students to make connection between the Geologic processes and human events (non-science topics) in an introductory Geology course. The topics of the study included relevance to historical, cultural, political, or economic issues in Africa such as climate change, bedrock geology, or development of the East African Rift. To achieve the research's goal the course was designed to engage students actively in-class and out-of-class exercises and activities. They worked in small groups to discuss and brainstorm in an effort to make connections to non-geologic topics. Other teaching methods such as simulations of debates, posters, summary reports, or laboratory activities were also employed. From written evaluations of the course, the majority of the students were able to connect 'the most geological' (such as strata graphic columns, geologic maps, plate tectonics reconstruction, radiometric dates) with hominoid evolution. In terms of thinking and problem-solving skills, students left the course in possession of long-term skills. This was aligned with the study of Trend (2004, 2005) and Hemmer *et al.* (2006 cited in King, 2008), that found that the linkage of environment and humanity issues with geological phenomena such as every day life or environmental hazards encourages students' interest in Earth science education.

Orion, Dubowski and Dodick (2000) developed a program that studied earthquakes via the use of multimedia as learning tools using software called "ASTOUND" with 32 senior high school students. The program was comprised of three phases: the introductory phase, independent study phase, and presentation phase. In the introductory phase, students were given materials such as articles, video clips, demonstrations, experiments, discussion, and field trips. In the independent study phase, the students worked in groups of 2-4 to choose topics for their research questions, to locate sources of information, to formulate hypothesizes, to build a work plan and to a submit report. Next, the students made multimedia presentations based upon their research. With the help of the software ASTOUND, they were able to maximize their presentation skills with dynamic slideshows, or by building various kinds of animation. This software was superior to other common software such as Power Point. In the last phase, students made their presentations to the class and visitors including Earth science researchers, inspectors of Earth science education, head masters, and other teachers. The finding showed that the use of experiments, field trips, and independent projects could lead to meaningful learning in Geology but the use of multimedia software could not guarantee the students really acquired the knowledge.

Some Geology concepts such as the rock cycle and Geologic time are abstract, and less familiar within human scale, the use of analogies can facilitate better student understanding of these concepts (Blake, 2004). For example, Blake explored 60 primary students' understanding of the rock cycle through using an analogy regarding the recycling of aluminum cans. To build the students understanding the teachers used two strategies: conceptual structures and analogies. In conceptual structures, students are encouraged to build mental models of the rock cycle. Analogies use every day common things that are more concrete to the learners to make the abstract concepts more clear. The aluminum can analogy represented the process of recycling (compared to the rock story) encompassed of raw materials (old rocks of the land surface), disposal (old rocks worn down and buried), making new materials (older rocks are made into new rocks), and re-appear (new rocks reach the surface). The researcher gathered data from practical rock tasks, students' concept maps, word association tasks, and interviews with additional probes. The results indicated that the students made a cognitive change in their understanding of classifying rocks by their formation rather than by their appearance or shape as a result of the aluminum can analogy. But educators must remember that the use of an analogy does not guarantee that all students will have a better understanding of the rock cycle. This limitation of using analogies to fully understand science concepts is aligned with other studies (Newton and Newton, 1995).

A growing body of research has been undertaken regarding the teaching strategy of fieldwork, or field trips as alternative strategy to build students' learning of Geology outside of the school environment (Orion and Hofstein, 1994; Hawley, 1998; Kean and Enochs, 2001; Marques, Praia and Kempa, 2003; Boyle *et al*., 2007; Knapp, 2007; Elkins, Elkins and Hemmings, 2008). Dodick and Orion (2003a: 207) noted that “experimentation and simulation in the laboratory, although an important component of many geological investigations could never be a substitute for evidence gathered in the field”. King (2008) indicated the key attribute of doing fieldwork is crucial and must be acquired in geo-science education. Students are given opportunities to maximize their learning potentiality in a number of ways. Fieldwork could facilitate a wide range of science process skills such as observation and recording data as well as thinking skills in ways that not available in the classroom, with a variety of scales, dimensions, and complexities. Additionally, students can benefit from out-of-school experiences in terms of supporting their cognitive understanding (Hawley, 1998) and influence long-term persistence of knowledge when the students directly associate it with active experiences from a fieldtrip (Knapp, 2007). Orion and Hofstein (1994) examined students’ understanding of Geology concepts prior to and after doing fieldwork and it became increasingly clear that students need to be involved in activities that encourage the sense of group work. Kempa and Orion (1996) indicate that students have a more positive perception of the educational benefits derived from group work done directly in the field. They also succeed better in completing tasks when working as a team. Additionally, learning from the outdoor world maximizes students’ interests, attitudes and values regarding geological education (Boyle *et al*., 2007; King, 2008).

Most teachers neglect out-of-school fieldwork to support the curriculum due to many reasons as noted in the work of Mason (1980) and Anderson (1980) also cited in Kean and Enochs (2001), Hanpipat and Roadrangka (in press, 2009). Most of the reasons were from external factors such as the intense structure of school curriculums or the lack of support. Teachers felt an obligation to cover certain amounts of content and that field trips would take away from this already precious classroom instruction time. They were also concerned about the safety of the students in the natural environment and other issues like funding and transportation. Instead teachers have been making an effort to use simulations of the natural environment via multimedia or computer software programs without leaving the classroom. Another issue keeping teachers from field trips is they were uncomfortable with the lack of knowledge or skills related to the field trip activity. As a result programs have been developed to strengthen and broaden teachers' content knowledge and skills so they will be more cooperative in planning future student field trips (Kean and Enochs, 2001). They developed programs to train teachers to serve as "teaming-up" for students' fieldwork. The training allowed teacher to attach to field experiences that they could use in the future trip.

The study of the use of fieldwork to enhance integration in Geological education was carried out in Portuguese schools (Marques *et al.*, 2003). This study had three aims: 1) to identify students' preparation for fieldwork such as the objectives and learning targets of the fieldwork and to plan the activities to be undertaken before the fieldwork occurred such as preparation for recording observations, making measurements, or collecting specimens, 2) to support teachers in developing the use of fieldwork in science teaching and 3) to make connections between the fieldwork and the school-based activities before and after the fieldwork. A hundred and three secondary students were given an opportunity to participate in fieldwork for two weeks. By responding to a questionnaire they had to evaluate their experiences regarding: preparation for the fieldwork, activities carried out during the fieldwork, and those after the fieldwork, formation and characteristics of their work groups, degree of contributions in the group, and their perceptions and attitudes towards the fieldwork. The results noted that the students seemed to develop better scientific skills and viewed fieldwork as useful to them in terms of giving them new information and understanding of Geological phenomena. Further, the fieldwork supported student social interaction when working in groups. The study also showed that the organization prior to and after conducting their fieldwork was problematic for them and thus the need for well-planned pre-preparation activities and the development of strategies for students' cooperative learning were suggested to accomplish the goals of fieldwork.

Field trips should be associated with other activities in the curriculum rather than done as isolated activities (Orion and Hofstein, 1994). For example, Chang (2005) implemented Earth System Education (ESE) for junior high school students (grades 1-9) in Taiwan, in conjunction with inquiry-based, problem-solving strategies, computer-assisted instruction (CAI), field trips, and teaching modules. The implementing of Earth-system integrated science topics with various teaching methods were assigned to the experimental-group students and the control group students received a traditional curriculum but with the same instructional materials, assessments, and equal amount of instructional time. Pre-test and post-test were given to the two groups in order to assess the students' learning, achievement, and attitudes towards science. The findings indicated that the students had positive gains in their learning, interest levels, and attitudes. In addition participating teachers showed positive and supportive attitudes toward implementing Earth System Education (ESE) and possessed optimistic opinions about the viability of implementing an integrated science curriculum in senior high schools.

An Integrated Curriculum

The older science curriculums in a great number of countries predominantly emphasized a traditional disciplined-oriented regime that involved mostly factual-based lecturing and the rote learning of copious amount of content. In Thailand, the transition into a new science curriculum that concentrated on science for all, the more constructivist teaching and learning approaches as well as using an integrated curriculum, provided alternative pathways to achieve the goals of educational reform. At the same time Earth science curriculums were being implemented in Israel, England, Wales and the United States that moved from the old way of teaching science content in separate disciplines to a more integrative approach (Orion *et al.*, 1999a, 1999b).

Forms of Integration

Integrated curriculums have been used in education in many different subject areas for many decades now. Integration of all areas has been seen as being most desirable in meeting real life expectations as in the real world most problems do not occur in isolation but are interdisciplinary in nature and require a multiplicity of skills to learn from those experiences, and to solve everyday problems (Frazee and Rudnitski, 1995; Czerniak *et al.*, 1999). It can be seen from numerous literature that the place of integration has not reached a uniform agreement of its meaning and approaches for teaching. A number of forms of integration are interpreted and exemplified by different authors or educators. Most of these forms describe integration in different levels as being like a spectrum. Some authors use the word integration but interpret its meaning in different ways. Common forms of integration frequently appear in literature: disciplinary, interdisciplinary, multidisciplinary, transdisciplinary, thematic approach, integrated, connected, integrative, and so on.

Pursova (1984) views integration as a system of the interpretation of reality reflected in the general relationships of all phenomena and processes. His point of view regarding system concepts consists of the natural, technical, and social sciences. However there was not uniform terminology used to distinguish explicitly these relationships in the system concepts, Pursova classified them based on “a varying degree of effort for generalization and abstraction in the individual sciences” (p.196). He distinguished the characteristics of a specific system of studying reality as: intra-disciplinary and inter-disciplinary system concepts in natural, technical and social sciences, and trans-disciplinary system concepts in philosophy.

a) Intra-disciplinary system concepts

“The purpose is to integrate the scientific facts of the individual disciplines of the same science without exceeding the scope of its own, physical, chemical, biological, sociological, or other spheres; this is an integration which is stimulated by a profound internal differentiation of the individual scientific disciplines. (p. 196)”. Intra-disciplinary represents the system’s cognition and solves the theoretical and methodological problems of one discipline.

b) Inter-disciplinary system concepts

The terminologies used in most literature were characterized as “marginal”, “boundary” or inter-disciplinary, sometimes also as “hybrid” branches of science in which the individual disciplines are frequently co-coordinated mechanically with one another (Pursova, 1984: 199). In addition, it was sometimes called “complex boundary disciplines" to clearly express the aspects of interaction, integration, hierarchism and complex methods.

The interaction and integration of scientific theories is taking place at several levels (Pursova, 1984: 200)

a) between the individual disciplines of the natural sciences (e.g. biophysics, nuclear chemistry, geochemistry, geophysics)

b) between the natural and technical sciences (e.g. bio-cybernetics); between the natural and social sciences (e.g. historical geography, social biology)

c) between the natural, technical and social sciences (e.g. social engineering)

The tendencies of the various branches of scientific knowledge have become better integrated, for broader and closer co-operation among the natural, technical and social disciplines to channel comprehensive research into the mainstream of development in modern science (Fedoseyev, 1984).

Jacobs (1989 cited in Frazee and Rudnitski, 1995) defined five options for integration addressed on a continuum from the less likely integration to most likely integration: disciplinary-based, parallel, multidisciplinary, interdisciplinary, and integrated.

Parallel (Beane, 1995) mentioned that the focus is still on separate subject areas, and therefore they are not really integrated. Frazee and Rudnitski (1995) described it as when two subjects are studied through concurrent events, such as reading a book from the time period that the students are studying in history.

Multidisciplinary (Drake, 1993 cited in McComas and Wang, 1998) noted that the multidisciplinary approach occurs when several teachers plan together, reaching a consensus on the focus of instruction. Following such planning, each instructor is then responsible for presenting the entire integrated lesson with crosssubject connections. Frazee and Rudnitski (1995) defined multidisciplinary units as those in which several subject areas center their contents around a theme and the teaching of each class is done as a separate unit. While Drake and Burns (2004) defined multidisciplinary approaches as focusing primarily on the disciplines and teachers use this approach to organize standards from the disciplines around a theme. The many approaches of the multidisciplinary are divided as follows:

Intradisciplinary emphasizes that teachers integrate the sub disciplines within a subject area. Integrated science integrates the perspectives of sub disciplines such as biology, chemistry, physics, and Earth and space science. Through this integration, teachers expect students to understand the connections between the different sub disciplines and their relationships to the real world.

Parallel disciplines approach addresses topics or themes through the lenses of several different subject areas. Students study topics or themes in different classrooms. Teachers have to organize the sequences of their contents to match the others in the different classrooms.

Interdisciplinary (Jacobs, 1989 cited in Lonning, DeFranco, and Weinland, 1998) noted that interdisciplinary referred to a knowledge view and curriculum approach that consciously applies methodology and language from more than one discipline to examine a central theme, issue, problem, topic, or experience which mostly uses social concerns (Ost, 1975 cited in Berlin and White, 1998). Moreover, Drake and Burns (2004) defined interdisciplinary integration as the common learning embedded in the disciplines in order to emphasize interdisciplinary skills and concepts. That is, connections between subject matters are emphasized, and they remain perceived in value in the unique characteristics and distinctions among the various disciplines (Lederman and Niess, 1997). Similarly, Czerniak *et al.*(1999) described each discipline as possessing unique conceptual, procedural, and epistemological differences that cannot be addresses through an integrated or thematic approach. Practically, teachers from different discipline teams teach the same group of students with each subject presented (McComas and Wang, 1998). It can be said that interdisciplinary still has the identity of each subject, while some parts of the concepts and skills are connected (Lederman and Niess, 1997).

Interdisciplinary merges courses of study for the purpose of instructional expediency into two or more bodies of knowledge. Theme is in the social issues and concerns. These might be two or more mini-courses that are team taught with little attempt to integrate the content conceptually (Ost, 1975 cited in Berlin and White, 1998). Drake (1993 cited in Mccomas and Wang, 1998) described interdisciplinary as teachers from different disciplines team teaching the same group of students, with each subject presented when the lesson requires specific elaboration.

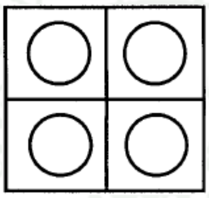
Integrated (Ost, 1975 cited in Berlin and White, 1998) stressed that the integrated model is often used in connection with mathematics and science. Integrated is really interdisciplinary, but at a more sophisticated level. Songer and Linn (1991) defined integration as the process of organizing information into broader categories and into more widely applicable ideas that resulted in knowledge integration. Integration means the synthesizing of ideas into a cohesive and coordinate whole. Sometimes integration means recognizing that two seemingly different processes are really explained by the same underlying principles. Jacobs (1989 cited in Frazee and Rudnitski,1995) defined integrating as the integration of subjects and content, skills, processes, and affective goals and activities that focus on the needs and interests of the students (Czerniak *et al*., 1999). There is more variety in instructional strategies and increased possibilities for new connections to be made.

Despite the long period of time that has passed in education, the definition of an integrated curriculum still remains uncertain. The wide range of ambiguous meanings of integration can be described as: This section collectively synthesized many forms or models of integration from key literature. Overall, different forms of integrated curriculums are viewed as the integration of three aspects: the integration of people, integration of activities, and integration of subjects (Braunger and Hart-Landsberg, 1994).

Integrated Curriculums according to Fogarty's Model

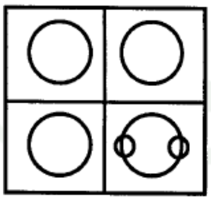
Fogarty (1991) classified ten views for integrating curricula. All ten models of integrated curriculums have a range of continuum with regards to the degree of connections. These are divided into three major aspects: within a single discipline, across several disciplines, and inside the mind of the learner as described below:

1. Fragmented



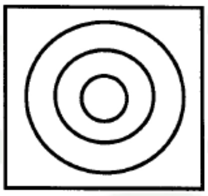
The curricula of most secondary schools adopt this model in which each discipline is taught by different teachers in different locations. Structures of school blocks mean students acquire isolated knowledge from different subjects and all content is viewed in fragments separately from each other. This traditional model allows teachers to work in their areas of expertise.

2. Connected



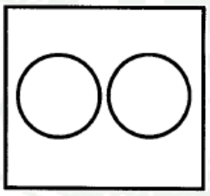
The Connect model provides a connection within each subject area. Each subject still has distinct characteristics and remains separate. The connection in the course is a concept in the related concepts, a skill to a related skill or other connecting works. Teachers play a key role in organizing related content into classroom activities rather than assuming that the students will build connections automatically. This model is most prevalently used in the primary or lower secondary levels.

3. Nested



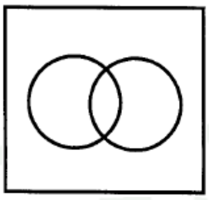
This model puts emphasis on multiple learning skills such as social skills (consensus seeking, summarizing, or attentive listening), organizational skills (building flow chart, web, or concept map), or thinking skills (comparison/contrast, generalization, or evaluation) as they relate to content-specific skills.

4. Sequenced



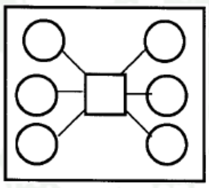
Topics or units of the study are rearranged and sequenced to coincide with each other. Two teachers might plan the order of the content so it parallels a particular period of time. Although these teachers still teach their own disciplines separately, the students can still make connections to the contents in both disciplines and thus more meaningful learning. In order to maximize the use of this model to build connections, teachers need to collaborate extensively with each other to create the best sequences.

5. Shared



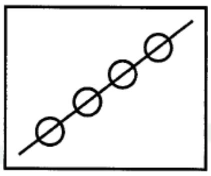
In this model the disciplines share mutual concepts, skills, and/or attitudes through well planned collaboration by teachers in other departments. They must have the view that disciplines have overlap and then look for these overlaps and plan accordingly. They may team teach the overlapped concepts, skills or attitudes and teach other topics separately at other times.

6. Webbed



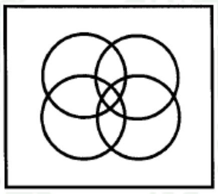
Webbed integration interconnects the multi-disciplines around a theme. This thematic approach needs considerable teacher collaborations in order to build conceptual themes from relevant concepts or topics. To build a theme, teachers have to seek out the connections between the subjects and weave a theme into all the content areas. This provides the most diversity of disciplines in studying one specific theme.

7. Threaded



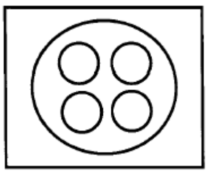
This model of integration concentrates on skills (social skill, thinking skill, or organization) that are clustered in and threaded throughout all the disciplines involved. The connections between and among the subject matters' content are not stressed and thus another curriculum is essential to cover all the content in all the subjects.

8. Integrated



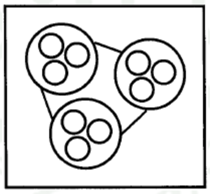
Unlike the shared model, the integrated model provides rich possibilities to interconnect many disciplines in a holistic view. All disciplines have interrelationships in terms of concepts or skills.

9. Immersed



In the immersed model, students play an important role to integrate the data themselves in their interested field of study. Students are responsible for their learning, searching for more knowledge, and building relationship from all the experiences they have. The integration is internally and intrinsically accomplished by the students with little or no outside intervention. Most of this type of integration occurs in the secondary or university levels.

10. Networked



The networked integration model addresses the idea of self-selected learning from an expanding boundary of knowledge with other expertise from other networks such as parents, scientists, or local communities. Students lead the direction in building networks as their primary source for learning.

It is clear that the models of integration in Fogarty (1991) have their own boundaries. This research adopted the Connected model as the starting point for the creation of an integrated curriculum in Geology. The Connected model provides guideline for teachers to integrate related content knowledge of other science subjects with geology content. Geology involves natural occurring phenomena that are attached to human’s every-day life experiences. In order for Geological phenomena to be understood there must be integration from many areas of science. In Thai classrooms science in the upper secondary levels is divided into physics, chemistry, biology and Earth science (Geology and Astronomy) in most schools there is only one or two teachers responsible for teaching the Earth Science topics. This small number is a barrier to collaboration and integration in the schools. Additionally the curriculum structure of science in the upper secondary level is overcrowded with content in physics, chemistry and biology.

Integration in Science Education

In 1968 for the first time a major international conference on the integration in science education was held in Bulgaria sponsored by Unesco in cooperation with the International Council of Scientific Unions (ICSU) and the Committee on the Teaching of Science (CTS). From this conference, came the guidelines that reflected international opinion regarding the development of courses in integrated science education. These guidelines consisted of five major conclusions which were (ICST, 1968; Chisman, 1990):

1. The teaching of integrated science contributes towards general education, emphasizes the fundamental unity of science and leads towards an understanding of the place of science in contemporary society. It avoids unnecessary repetition and permits the introduction of intermediate disciplines.

2. A course of integrated science should emphasize the importance of observation for increased understanding of the environment; it should introduce pupils to logical thinking and the scientific method.

3. As it may be necessary in an integrated course to omit some details, it is essential that the content of a course be judiciously chosen. It must be carefully compiled by collaboration between the different teachers and other specialists.

4. The extent of integration and the balance between integration and co-ordination will depend on the age of the pupils, the type of educational institution and local conditions. At the earlier stages of secondary education, a totally integrated course in experimental science appears generally desirable. At the higher stages of secondary education such a course may also be desirable, especially for those students who have decided not to specialize in science.

5. Science is an important part of primary education, particularly in arousing scientific curiosity and in developing scientific attitudes and skills.

Chisman (1990) suggested that creating curriculum models for integrated science teaching in primary and secondary school should concern five areas:

1. The factual and theoretical knowledge of science
2. The processes of scientific investigation and reasoning
3. Practical (laboratory) investigation in science
4. Attitudes towards science and attitudes associated with science
5. The relationship of science to society

The Inter-Union Commission on Science Teaching reported the conclusions from the congress on the integration of science teaching in 1968. A course of integration should emphasize the importance of observation for increased understanding of the environment. It should introduce pupils to logical thinking and the scientific method. Typically, integration in science should emphasize two main components of learning science: knowledge and the process skills. Jacobson (1968) noted that an integrated program permitted students to have the experiences of applying some of the fundamental knowledge in different science areas. “There are reasons to believe that students gain a more profound understanding of such basic ideas when they apply them in a variety of scientific fields (p.76)”. Not only is scientific knowledge integrated in a diverse field of science, process skills can also be developed in several areas of science. It requires a great deal of critical process skills, to develop model formation through integration in many topics such as the solar system, genetics, or electricity (Jacobson, 1968).

There are a variety of approaches to teaching integration. Each unit of science concepts might use a different type of approach. Jacobson (1968) recommended different types of teaching approaches: laboratory experimentation, field research, investigations in science, student research and projects, theory and model building, lecture demonstrations, systematic observation and prediction, instrumentation in science, measurement and data interpretation or the case history approach. Certainly, there is no one best approach to teaching integrated science. What ever the chosen approach to integration it should be flexible for teachers to plan and organize the integration regarding to the appropriateness of the concepts of each unit, their students' prior knowledge, or any other constraints (e.g. time, or resources). Some teachers might choose one of these approaches when teaching one particular unit; while others might use multiple approaches at the same time. There is not one uniform way of teaching integration even when teaching the same unit because of the difference in teaching situations regarding students, school atmosphere or even available resources.

Showalter (personal communication, November 7, 1996 cited in Mccomas and Wang, 1998) described "integrated science as functional units of learning and teaching that contain elements of science and one or more other ways of knowing". Integrated science curriculums must reflect modern content that involves higher order thinking, learning to learn skills, and the use of science in human affairs that are concerned with values, ethics, probabilities, policy, preference, or limitations of knowledge (Hurd, 1991).

Integration in the Current Basic Education Curriculum B.E. 2544

There are a number of literatures defining integration in educational system and many definitions as reviewed earlier. Thai education after it went through an educational reform concentrated on the development of human resources to enable them to live in an era of globalization. The Basic Education Curriculum B.E. 2544 (MOE, 2002) states that integrated teaching is an effective teaching method when it involves the interrelationship of several subjects rather than fragmented content knowledge in separate subjects. Integration is the interrelationship that occurs in the diverse areas of content knowledge, thinking, and process skills in order to apply these to real-life situations. Therefore, different forms and methodologies shall be applied to each level including learning management, emphasizing actual teaching-learning situations, self learning, group learning, learning from nature, performing actual practices, and integrated learning. The Basic Education Curriculum B.E. 2544 (MOE, 2002) defined two general types of integrated teaching including integration within the same field and integration from other fields. Integration within the same field is instruction that interconnects knowledge, process skills, and learning outcomes from each field. The other is instruction that relates at least two other fields with knowledge, process skills, and learning outcomes in each field. There are four other forms of integration that differ in further details as follows (MOE, 2002):

1.Integration by one instructor, the individual teacher may link one theme or one subject concerned with real life or stipulated subjects. Linkages between various subjects and learning procedures may also be undertaken.

2.Integration by two or more instructors, two or more instructors jointly work out integration to teach one specific theme or subject, on a parallel activities basis.

3.Multi-discipline integration, where subjects from different groups are integrated to replace normal learning management by each individual instructor teaching each subject or each subject group separately.

4.Integration by project learning approach, where learners and instructors jointly create a project for integrated teaching and learning. The project will run continuously, with many hours of learning time for each subject put together. Different subjects are combined to achieve common goals. This is teaching and learning as a team. In the event it is necessary to emphasize skills for a particular subject, learning management can be singled out.

Although there have been dramatic changes in the science curriculum from the elementary levels to upper secondary levels, there are some similarities between the former curriculum and the recent one. Integration is always involved in the teaching and learning of science in the elementary and lower secondary levels; whilst upper secondary science curriculum often concentrate on fragmented science disciplines with more complicated content. In the light of the reforms outlined in the Basic Education Curriculum B.E. 2544, the new vision for science learning was for greater understanding and better appreciation of nature and the environment. This viewpoint entails that learners must integrate various diverse disciplines to development creativity towards more quality of life. It should also enhance the ability for collaboration in managing the natural world and make for more sustainability (IPST, 2001). Although educational reform puts intense emphasis upon the use of an integrated curriculum the call implementation has been great, but in actuality it has not become common place in schools. Teachers are finding it quite difficult to put an integrated curriculum into practice at the classroom level and most high school around the world still use a subject based curriculum (McCormas and Wang, 1998).

Benefits of an Integrated Curriculum

The benefits of an integrated curriculum for students can be considered by examining the outcomes of several domains: cognitive, skills, social, and affective.

1.Cognitive outcomes: There are a considerable number of literatures that reveal the benefits of an integrated curriculum in increasing cognitive purposes. An integrated curriculum can increase students' content knowledge and form deeper understandings related to them (Green, 1991; Vars, 1991; Berlin and Hillen, 1994; McComas and Wang, 1998; Meier *et al.* , 1999). Additionally such curriculums help students to create organized systems and promote more connected, organized, and transference of understanding from one context to another (Frazee and Rudnitski, 1995; Beane, 1995). In science practice, students can apply science in their daily lives by learning science in a connected and context-rich fashion through integrating science (McComas and Wang, 1998).

2.Skills outcomes: The development of skills, such as the scientific process skills, communication skills, manipulation skills, was demonstrated in Berlin and Hillen (1994). Likewise, there were increases in problem solving ability (Shann, 1977 cited in Meier *et al.*, 1999).

3.Social outcomes: Integrated curriculums promoted students' self worth and their socialization skills because when students worked in groups they had to increase their interactions with their peers and this helped to improve classroom behaviors (Berlin and Hillen, 1994).

4.Affective outcomes: Several studies demonstrated greater interest and motivation in science when students was presented with science as an integrated discipline rather than as subject-based programs because integrating science enables the use of real world themes to develop or maintain students' interests (Berlin and Hillen, 1994; McComas and Wang, 1998; Revetta and Das, 2002). Furthermore, teachers' attitudes toward teaching science as integrated disciplined have shown a shift from being reluctant to one of openness and enthusiasm (Green, 1991).

Challenges in implementing an Integrated Curriculum

1.The concern that the integrated content taught matches desired standard outcomes is problematic (Meier *et al.*, 1999). Parents of secondary students expressed concern that their children will not be sufficiently academically challenged by curricula that are not disciplined-based and centered on facts. They fear that non-standards will go against their children when it comes to getting into colleges which may have more rigorous standards (Frazee and Rudnitski, 1995).

2.In some countries, teacher education programs that prepare them to teach in an integrated fashion do not exist and as a result teachers have no background or experience in using an integrated science approach in either primary or secondary schools. Teachers were uncomfortable to teach an integrated curriculum because they did not have the training to teach it (Green, 1991). In fact, undergraduate teachers lack the opportunity in experiencing the integrated curriculum in their college classes (Czerniak *et al.*, 1999). Teachers who certify at the secondary level usually in a specific field of study have limited in-depth knowledge of other subjects areas because they do not take a range of science course to provide them with the necessary depth and breadth of content (McComas and Wang, 1998; Meier *et al.*, 1999). Chisman (1990) suggested solutions for improving teachers' teaching integrated science by setting up programs of in-service teacher education on the content and techniques of integration in science associated with professional support and incentives for teachers such as teaching and learning resources, or collaboration with teachers. "Importantly, programs should be aimed at developing hands-on experiences in teaching integrated science rather than allowing teachers just to read about it (p.16)."

3.Lack of belief in teachers' abilities to teach an integrated curriculum might lead them to lack motivation for using it at all or to become less effective in implementing the curriculum (McComas and Wang, 1998). When teaches faced problems due to their lack of experience in integration, they feel fear and reluctant to teach integrated science. Definitely, teachers feel more comfortable to teach single disciplines relating to their academic expertise and thus they feel it is not easy for them to teach other disciplines which are out-of-their-field of expertise (Chisman, 1990). Similarly, students' belief also influences knowledge integration. They may not integrate knowledge presented in science if they believe that science consists of isolated principles (Songer and Linn, 1991).

4.Effective integration in science requires the collaboration of teachers in different subjects to dissolve the boundaries between their subjects. Practically, school structure does not allow enough time to integrate and therefore, teachers do not have the opportunity to work with other teachers (Jacob, 1989 cited in Czerniak *et al*., 1999; Meier *et al.*, 1999).

5.Assessment: student assessment limits implementing an integrated curriculum (Czerniak *et al*., 1999). Most tests still examine content separately rather than student performance. In fact, the study showed that while students scored better in open-ended problem solving, they scored lower on multiple-choice, procedural-based skills. The traditional standardized tests probably do not show the positive effects of the integrated curriculum (Meier *et al.*, 1999).

Previous Research on Implementing an Integrated Curriculum in Teaching Geology

Suggestions of the Inter-Union Commission on the Teaching of Science (1968: 26) illustrated the importance of integration in Geology content as followed:

> …Geology is not, in the opinion of many experts, an appropriate course to be taught independently at the secondary school level but it is an appropriate central discipline in the teaching of an integrated course in

geo-science or Earth science …The physical sciences, biological sciences and mathematics play important roles in the integration of sciences in this program…

As some literature has stated, several Geological conceptions have relied heavily on the understanding of the basic principles of physics (Gobert, 2000; Revetta and Das, 2002; Libarkin *et al.*, 2005). Also, the Teacher's Manual of Earth and Space Science (IPST, 2005a) is written with some physics concepts and chemistry concepts as prerequisite concepts to learning Geology at the upper secondary grade levels. For example, the concepts regarding Geological phenomena like earthquakes, are explained based on physics topics that include wave propagation, seismic waves, wave velocities, reflection and refraction of seismic waves, and elastic modules. Likewise, the movement of plate boundaries can be explained using the concepts inert in potential energy, heat energy, heat transfer, force and motion. The explanation of Geological history requires an understanding of chemistry concepts that discuss half life of radioactivity or the isotopes of radioactive elements in dating rocks or fossils.

This section will discuss research that has studied efforts made to enhance the effectiveness of education in Earth science and thus Geology through developing an integrated curriculum. The discussion will include the use of an integrated curriculum, the concepts, and the related challenges.

Integration of Biology with Geology

Dodick and Orion (2003b) designed a curriculum "From Dinosaurs to Darwin" to emphasize concepts of evolution with Geologic time periods. A class of twenty-two Earth science Israeli students in an urban high school with little or no background in biology constituted the participants. The study of evolution means studying living things and is a very abstract concept, but it can become more concrete if the evidence in fossil records is used as an investigative approach. Dodick and Orion's curriculum built in links between the evolutionary changes that have affected the Earth's biota in Geologic time periods, rather than providing the evolutionary mechanism itself as is typically the focus of biology. Thus, activities of the program put emphasis on defining the basic materials of a fossil investigation, and understanding the temporal relations between such materials to construct the idea of the environment and evolution. The first activity introduced the definition of fossils and rocks based on the textbook. The students then participated in an all day field trip to develop their understanding of the relationships between fossils and evolutionary changes in time. In the evolution and the fossil record activity, students debated the issue of the large-scale changes in evolution that occur in Geological time, discussing how scientists might reconstruct the idea of adaptation from extinct organisms, the evolution of new groups of animals, rates of evolution, or physical causes of catastrophic extinction. The last activity was to establish research projects concentrating on macro-evolutionary change such as the evolution of birds, mass extinction or modeling Geological time.

Integration of Physics with Geology

Earth context in the National Curriculum for Science in England for 11-16 year-old students can be analyzed and structured in an area of physics. King and Kennett (2002a) identified 25 overall Earth science concepts that are related to a number of physics concepts. Particularly, in the content of Geology, they classified the concepts of physics into three major areas. First, forces and motion relates to the Earth's gravitational field, friction and therefore earthquakes. Second, the reflection or refraction of waves relates to coastal waves or seismic wave reflection or refraction and lastly, radioactivity and the role of half-life in dating rocks. King and Kennett (2002b) suggested numerous activities to integrate physics concepts into the content of Geology. For example, teachers may consider teaching the meaning of half-life within the topic of dating rocks by radioactive methods. To illustrate the concept of half-life, teachers could use a simple simulation of decay by using M&M chocolates. Students are given a number of M&M's which are thrown into a tray that simulates on half-life the M&M's that land with the logo down are regarded as having already decayed and are counted or discarded. The remaining is thrown again and the activity is repeated until there are only a few left. Students plot the number of M&M's versus the number of throws on a graph to represent the real half-life curve.

Revetta and Das (2002) developed a course in Geo-physics at the university level using an integrated approach. The physics and Geology teachers collaborated together and were able to build connections between principles in physics with Geological issues present in local communities. The course emphasized hands-on activities with labs experiments, field study and computer analysis of data gathered by students in the course. The course was divided into two sections, first the physics section where the principles underlining seismic activity, resistivity, gravity and magnetic methods were used in the field, in discussion with peers and while doing hands-on and minds-on activities like determining wave speeds or the density of the Earth. The second part involved field projects where the students worked our real problems that required the use of physics' principles taught in the first part. For example, an understanding of wave propagation, seismic waves, reflection and refraction of seismic waves was required to determine the depth of bedrock in ground water. As well there was a relationship between using electrical resistance to located ground water resources and the depth of the bedrock and the use of gravitational surveys to construct a subsurface Geological map. This integration was done in an effort to make science teaching and learning more effective, interesting, and motivating to students by working on real-world problems and learn how to acquire, analyze, and interpret related scientific data.

Chang and Taipei (2002) referred to science education in Taiwan who had developed the Science and Life Technology Curriculum Standards (SaLTS) which aimed to integrate a range of science subject matters' concepts from biology, chemistry, Earth science, physics, and life technology. This standard is the foundation of the Earth Systems Education (ESE) which puts emphasis upon the individual level, individual and social level and individual and nature level.

Professional Development

Is this the Time for Changes Science Teacher Development in Thailand

Generally in Thailand, science, mathematics, and technology teachers typically receive training conducted by the Institute for the Promotion of the Teaching of

Science and Technology (IPST) which provides intensive in-service training for science, mathematics, and technology teachers. Typically, IPST has conducted teachers' training in three ways:

1.Workshops for in-service teachers have been held by IPST themselves during the summer break of the school year in order to increase teachers' content knowledge and teaching skills; however, these workshops can only have a limited number of participants.

2.The project of cooperation within a network of 24 public university faculties of science and mathematics, a group of outstanding teachers who have fairly high aptitudes in teaching practices are chosen to be, so called leader-teachers. All of them are trained both in content knowledge and scientific process skills by university staffs in collaboration with IPST ones. The workshop is usually four whole days and when the participants complete the workshop they are in charge of distributing their knowledge and teaching skills to their colleagues in the same school or schools within the same district (IPST, 2003).

3.The Educational Television station (ETV), in collaboration with IPST, the Department of Non-Formal Education, and the Ministry of Education (MOE), is another means of training science and mathematics teachers, particularly in the lower secondary levels, using long distance satellite (IPST, 2004a). This project is aimed at training teachers who would not normally have a chance to attend workshops because they live in remote areas. Teachers who receive this professional development can promote both content knowledge and the processes of teaching and learning amongst their colleagues. The greatest advantage to this is that a large number of people can take part at one time in remote sites. However, ETV provides only one-way communication and there is no method for interaction.

Recently, IPST established a new project aimed at developing in-service teachers both primary and secondary levels to improve teaching and learning science, mathematics, and technology. With collaboration among IPST, the Office of the Basic Education Commission and the Commission on Higher Education, the project has been continually running for 5 years, 2007-2011. To develop in-service teachers in 178 school districts, the ultimate strategy is to use direct and long distance training via ETV in cooperation with notable schools to be places for building teacher learning communities. These schools which have high potentials in science and mathematics are chosen from each school district to take part in the project. IPST and university faculties contribute in-service teachers to serve as mentors for other teachers in the participating schools and neighboring schools as locations for providing long distance training through ETV and for other schools in even remoter areas. Direct training for science and mathematics teachers is held by eight universities in all regions of the country: Chulalongkorn University, SrinakharinWirot University, Chiang Mai University, Silpakorn University, Kasetsart University, Khon Kaen University, Ubon Rajathanee University, and Naresuan University. Teachers learn a number of complicated science concepts in 5 major subjects (physics, chemistry, biology, Earth science and astronomy, and mathematics) and teaching methods for encouraging thinking, analyzing and problem solving skills. The training takes about 100-120 hours within a three year period. These trained teachers are necessary participants serving as direct trainers or mentors for other target schools. Further details of this project are available online at http://ttlc.ipst.ac.th/.

Most professional development in science education in Thailand is of the authoritative top-down type with supervision and advisement occurring outside the expertise of the schools. Although IPST conducts teacher professional development in order to push the educational reforms regarding the student-centered approach, the traditional forms of professional development persist. Teachers are usually subjected to the “one-shot workshop” either developed by IPST or a university, using topics from disconnected classes (Lewis, 2002). Teachers have learned from teaching-by-telling by “experts” more than learning from their own knowledge (Loucks-Horsley, 1995). This is not truly personal professional development.

Both IPST and faculties of education have not made enough of an effort to provide the necessary leadership in understanding and implementing educational reform and teacher development (Pillay, 2002). The teaching approaches delivered to in-service teachers is like a cookbook recipe delivered within the workshop format or a short course delivering advice on good teaching practices (Kember and McKay, 1996). Because students are so varied, teachers are heterogeneously qualified and school situations vary one true recipe for good teaching does not exist and if it did it would not be the solution for every teaching or learning situation. Teachers may also have difficulty implementing what they have learned in the workshop to their own classroom situation. Therefore, a paradigm shift in professional development is needed to improve the quality of teachers as an ongoing process from their undergraduate years to the end of a professional career (IPST, 2002).

The Call for Reform of Professional Development

Conventional methods of conducting pre-service and in-service education and professional development such as seminars, or workshops have not always proved to be adequate for attaining the goal of education reform. In-service workshops conducted all over the world have been usually too short and occasional to foster a transformation in teachers' classroom practices. The traditional forms of professional development are widely criticized as being ineffective in content necessary for increasing the teacher's knowledge. Teachers adopted the knowledge without concern for its appropriateness in a personal and educational context. Teachers adopted the teaching and learning processes from told to them by outsiders who were conducting the workshops and adapting them into their instruction. In other words, they do not possess the ownership and the empowerment of their teaching (Pedretti and Hodson, 1995). It is these kinds of opportunities that enable teachers to learn about themselves and develop a sense of efficacy in making decisions on their own classroom teaching.

Key Characteristics of Reformed Professional Development

Reformed professional development is derived from teachers and their contexts (Cochran-Smith and Lytle, 1990; Fullan 1991cited in Loucks-Horsley, 1995; Lieberman, 1995; Black, 1996; Maldonado, 2002). The principles of effective professional development should be shifted from a top-down approach to bottom-up one. Professional development should be formats that put teachers in the center of scheme connected with classroom life. The development of the profession should initiate from personal dissatisfaction or problems in specific classroom contexts such as the learning by students in the classroom or the lack of confidence to implement the new curriculum and so on. Individuals are aware of these frustrations and should try to seek their own solutions for these problems that are the heart of professional development. Despite these issues being extremely important to teachers' teaching practices they are frequently neglected as the key issues in which to organize simple workshops. They also need workshops that deal with these "simple issues" such as class size, learning environment, or facilities and social context such as relationships between teachers and students, classroom interaction just as importantly as they need them regarding content integration.

Reformed professional development is one that gives teachers the opportunity to be reflective practitioners (Black, 1996; Maldonado, 2002). Maldonado defined a model of effective professional development called "observer/assessment model" in which teachers reflect on their teaching practices themselves or receive feedback from colleagues as well as seeking help in an effort to change their practices. Teachers are able their own new knowledge and skills through personal reflection.

Reformed professional development means raising teachers' ownership of their development and having them involved in active learning (Cochran-Smith and Lytle, 1990; Little, 1993; Bell and Gilbert, 1994; Maldonado, 2002). Teachers are actively engaged with ideas, materials, skills or experiences in their practices rather than being passive participants in traditional workshops. This generates the sense of equity, self-initiated work and provides a comfort-zone for talking about the curriculum. Teachers should recognize their unique expertise and limitations in their intellectual and skills resources to control and drive their own professional development. The input of teachers' ownership empowers them and raises their status which enables them to make their own decisions regarding how to improve their students learning skills. Not only does this bring about development of them as professionals it also provides for personal development.

Reformed professional development is build upon the idea of teachers' developing a collegial network and community with a long duration (Cochran-Smith and Lytle, 1990; Lytle and Fecho, 1991; Lieberman, 1995; Garet *et al.*, 2001; Maldonado, 2002). The development of a collegial environment is the first step to improving their teaching and learning while at the same time working collaboratively with other teachers in a professional development program. Teachers should be allowed to work collaboratively with teachers in the same schools, grades, or subject areas. The school context is the place for teachers to discuss, share ideas, talk with each other, and learn and solve problems in context. Collaborative groups can serve as a resource for teachers to further develop their understanding of teaching and learning (Loucks-Horsley, Hewson, Love and Stiles, 1998 cited in Maldonado, 2002). Working with other teachers in a collaborative effort can also be used to bridge the community of practitioners who can listen and share their circumstances and difficulties in the classroom and how they deal with them. Teaching is not only viewed as an individual and private effort, but also as part of a team in which teachers support each other and enrich each other's work.

Reformed professional development should be done on a daily basis and be seen as being practical (Darling-Hammond and McLaughlin, 1995; Garet *et al.*, 2001). Teachers should not see professional development as only an out-of-school activity and that learning of this type has to occur in workshops. They should believe that effective professional development can occur in the classroom and be conducive to other school activities. Professional development can take place during the regular school day on something as simple as the process of planning or classroom instruction. Hence, this form of professional development easily makes connection between regular teaching and the classroom situation with the ongoing process of improving professional growth.

Action Research

Action Research as a Professional Development

Traditional professional development emphasized teachers' content knowledge and skills without relating it to their backgrounds, contexts, and their expertise. Because of this most teachers are unable to apply what they have learned in professional development sessions in their classroom (Lewis, 2002). Professional development should provide opportunities for teachers to maximize their students' learning and improve their own classroom practices. Action research should be considered as a means to better enable the goals of professional development to be more accurately met. Teachers who engage in action research usually become more aware of their own practices and what their students are thinking, feeling, and learning. Involvement in an action research group creates a new social setting. A set of new relationships, discourses, and practices are established. The action research group thus becomes a combination of personal beliefs and practices, and the beliefs and practices of the other members (Pedretti and Hodson, 1995).

Definitions of Action Research in Educational Literature

There are a great number of definitions of action research with respect to emphasis. The standard definition of action research is given as:

> …Action research is a form of collective *self-reflective* enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situations in which these practices are carried out … The approach is only action research when it is collaborative, though it is important to realize that the action research of the group is achieved through the critically examined action of individual group members (Kemmis and McTaggart, 1988 cited in Webb, 1996: 147)

Elliott (1991 cited in Mcniff, Lomax, and Whitehead, 1996) emphasizes action research for improving practice rather than producing knowledge. All teachers as practitioners can do it as an integral part of their daily practices (Lieberman, 1995). It should be collegial, contextual, and supportive of the teacher's efforts. It is an ongoing process for teachers to be self-investigating practitioners who logically and systematically examine their own teaching (Nolen and Putten, 2007), after analysis collaborate with others the consequences of some classroom actions (Tabachnick and Zeichner, 1999), and produce and develop an appropriate sequence (Winter, 1996).

Overall, the definitions of action research are similar to other research in terms of using logical and systematic inquiry to do the research but the intentions of action research are different from other research and these differences are described in the following section.

The Diverse Goals of Action Research

1) Desire for change

The goal of action research is to give teachers the opportunity to improve their own personal practices (Mcniff, Lomax, and Whitehead, 1996). It is initiated when a teacher recognizes a problem or an unintended occurrence happens in the classroom. They recognize they have a desire to make changes and action research allows practitioners to gain knowledge and skills in research methods and applications making them more aware of some possibilities they could use to transform their practices (Oja and Smulyan, 1989; Kember and McKay, 1996; Raymond and Leinenbach, 2000). This valuable recognition comes from “the grassroots of the profession”, or from those who are working on the frontlines of the classroom (Cochran-Smith and Lytle, 1990; Hargreaves, 1994). Importantly, teachers as the classroom insiders themselves have to have the desire to change their teaching practices rather than because someone outside has said they must. Otherwise, the practice of teachers might be misdirected to change and the results may not be appropriate. Therefore, it can be seen that action research is an alternative way of initiating change, but it is based upon the change happening as a result of the teachers’ needs and not because of someone telling them they must change.

2) Practicality

Prior to teachers being able to improve their pedagogy as it relates to a specific situation using action research they need to be aware of their present practices and themselves questions such as “Is a new method practical rather than whether it will work?” or “Does it fit with the context and does it suits the person?” or “Is it in line with their purposes?” and “Does it help or harm their interests” (Hargreaves, 1994). In the other words, action research is based on the value of change being dependent upon helping practitioners gain more appreciation for the action as it fits their own teaching situation and make the decisions themselves. Action research is done by practitioners who are in the situation rather than by academics or researchers who know very little about the situation (Mcniff and Whitehead, 2006). In conventional research, teachers are often dissatisfied with the new knowledge or interventions that they instigate or proclaim to the teachers and expect them to put them into practice in their classrooms pattern of the (Oja and Smulyan, 1989). Frequently, the implementation of the research does not match with practitioners' situations and may not even make sense to them. It may conflict with the teacher's need to improve by using new knowledge or teaching methods, but in the end the usefulness is limited because the area of research was not appropriate for the teacher's situation and was simply decided by the researcher without consulting the teachers. It is a vital key to action research that the what and why be considered carefully to ensure it is the most appropriate method for changing teachers' teaching practices and that it fits with their situations (Hargreaves, 1994). Some pedagogy does not work in all situations.

3) Empowerment and ownership

One of the important considerations for positive teacher change is to involve them or give them more ownership of the change. Teachers should have the opportunity to take a leadership role and be able to establish a community for collaboration in their workplaces (Hargreaves, 1994). To change their practices, they should not be told what to do but decide for themselves or in negotiation with their workplace colleagues (Pedretti and Hodson, 1995; Mcniff and Whitehead, 2006). Action research emphasizes the involvement of teachers' examining problems in their own classrooms (Thompson, 1996; Mcniff, Lomax, and Whitehead, 1996) and puts the responsibility for their professional development in their own hands rather than having them simply acquire knowledge (Oja and Smulyan, 1989). The key terms in action research are empowerment and ownership. Empowerment is there to make sure the teachers have control over their own professional development and to enable them to develop their own creative teaching models that are appropriate for their specific situation (Fry, 2002). In other word, teachers who actively act are those who have a deep personal understanding of the issues and feel a personal investment in addressing and solving the problems (Pedretti and Hodson, 1995).

4) Decentralization

Unlike traditional research, action research concentrates on the local context of practitioners rather than generating generalized pedagogy or skills. Stringer (2007: xi) notes that “Without intimate knowledge of the local context, one cannot hope to devise solutions to local problems”. He also suggests that “centralized policies and programs generated by ‘experts’ have limited success in overcoming problems (p. xii). In normal schools, there is no effort to combine research into their practices. The separation between research and practice is explicitly distinct (Schon, 1987). However, action research is regarded as an ongoing process to develop teachers’ learning in a profession associated with teachers’ regular work.

5) The Notion of Practitioners: Professional Knowledge

Action research is the appropriate research for anyone who would like to improve themselves or make changes to improve their workplace situation. The heart of action research is the idea that the practitioners themselves actually do the research. An issue can occur among the practitioners as to how they could possibly do the research as it work usually done by academics or official researchers. Donald Schon (1987) proposed the topography of professional practice to present the metaphor of contour and different height of professional landscapes (Mcniff and Whitehead, 2006). Schon defined two sources of dilemma in professional practice: 1) the prevailing idea of rigorous professional knowledge, based on technical rationality, 2) awareness of indeterminate, swampy zones of practice (p. 3). Technical rationality is based on the epistemology of positivism. Practitioners are instrumental problem solvers who select technical means best suited to particular purposes with highly applied theory and techniques from systematic scientific knowledge.

A Variety of Types of Action Research

Action research in various fields has a long history and perspectives. It can be seen in the different works of Kurt Lewin, Stephen Corey, John Elliott, Lawrence Stenhouse, Kemmis and McTargart. Action research in the area of education really began to be used more often in the United States in the early 1990's. But as early as the 1930's it was used by Kurt Lewin for solving social problems in the field of education. Later in the 1940s Stephen Corey adopted Lewin's approach towards school work. Corey's process of action research involved using the scientific method when generating problems, formulating hypothesizes, making predictions, recording data, and forming generalizations from evidence (Zeichner, 2001). This type of action research was generally controlled by outside researchers (Smith, 1996). Action research began to flourish in the United Kingdom in the early 1960's. John Elliott and Lawrence Stenhouse introduced action research to be used at the secondary level and they viewed action research as a teacher-as-researcher, self-monitoring process, and teaching as a reflexive practice. The outside researchers could facilitate teachers to improve their teaching practices. Their efforts led them to establishment the collaborative action research network (CARN). Another type of action research was established in the 1970's by Australian scholar Kemmis who introduced the emancipatory action research based on a critical paradigm. The critical action research intended to promote wider democratic reforms and social justice to change policies in schools and the society (Zeichner, 2001). The process included continuing cycles of planning, acting, observing, and reflecting.

Carr and Kemmis (1986 cited in Zeichner, 2001) distinguished action research into three types: into technical, practical and emancipatory. These three types of action research all aim to improve teachers' teaching practices with different degrees of teacher involvement and collaboration of facilitators. Technical action research is positioned at the end of the continuum and it seeks for effectiveness of practice in professional development depending on an outside facilitator. Emancipatory action research, by contrast, is at the other end of the continuum, and it aims to improve teachers' better understanding of how to transform their practices and systems by intensively concentrating on empowering the teachers and making them more responsible for effecting the changes. The collaboration of facilitators as "community of scholars" plays an important role in influencing the teachers' research.

The current types of action research are distinguished into different types. Zuber-Skerritt (1996) established the theory and practice of emancipatory or critical action research based on the critical theory. Emancipatory action research focuses on collaborative, critical and self-critical inquiry by practitioners of problems in their own practice. It is a cyclical process involving planning, action, observation (self-evaluation) and critical reflection. While Stringer (1996) introduced the community-based action research that engaged stakeholders (teachers, administrators, students, parents) directly in creating solutions for problems in their community.

Calhoun (1993) describes action research regarding the number of teachers conducting the research. Basically, individual teachers can perform classroom action research on a particular subject or teaching method in order to improve his/her teaching practice. While groups of teachers work collaboratively with university researchers on conducting action research called collaborative action research (Sagor and Curley, 1991; Calhoun, 1993). The last type is school wide action research which engages teachers in entire departments and administrators in schools. Lewin's model of action research noted that action research is portrayed as a spiral process involving the steps of planning, acting, observing, and reflecting (Cohen, Manion and Morrison, 2000).

Capobianco and Feldman (2006) distinguished action research by regarding in relation to the dimension of participation of the university researchers and school teachers involved in the collaborative action research. The first-order action research concentrates on the role of teachers as the key agent performing the action research. While the second-order action research focuses more on the facilitation of university researchers for developing the action research for the teachers. Llorens (1994) places action research into three types including teacher-originated, administration-directed, and collaborative action research. In summary, most action researches involves a group of teachers working together and establishing a community of learning to reach their goals of professional development, science learning, and curriculum development.

Research Related to Using Action Research

Action research has been utilized in three domains of science education: teacher education and professional development (Tabachnick and Zeichner, 1999), research on the learning of science, and curriculum development and implementation (Pedretti and Hodson, 1995). First, action research has been used in both pre-service and in-service science teacher education. Tabachnick and Zeichner (1999) used action research to help prospective teachers become more reflective about what it means to teach for conceptual change. Prospective teachers designed, conducted, and presented research projects, used reflective journals as research notebooks, and participated in seminars. The process was found to help participants focus more on student conceptions and explanations, which are important aspects of teaching for conceptual change. Additionally, Capobianco (2007) studied the transformation of teacher practices by conducting action research on feminist science teaching. The family of 11 practitioners for different schools engaged in systematic, self-critical inquiry of their own practices and joined collaboratively to develop a better understanding of how science can be taught to a more diverse group of students. As a result, teachers gained new knowledge about feminist pedagogy for inclusion into their science teaching. Secondly, as a research project on the learning of science, the Project for Enhancing Effective Learning (PEEL) involved a group of teachers who had concerns about the way students approached learning. Teachers were given a valuable opportunity to debate and exchange exciting new ideas on their teaching and learning practices (Mitchell and Mitchell, 2008). Lastly, some studies intended to employ action research to develop curriculum materials (Pedretti and Hodson, 1995) based on science, technology, and society (STS) education. Action research assisted participating teachers by showing them how to learn about educational issues, how to formulate their own views on curriculum, and how to critique and develop their own educational practices.

Despite the fact that the idea of action research has been around for a long time in several international countries the idea of it is quite new to Thailand and its education system. The National Education Act B.E. 2542 (1999) (ONEC, 1999) mandates teachers should rely on the use of self-development for improving their classroom practices as the best way to facilitate these improvements. Development is based upon the standard-based document being delivered to every teacher across the country.

Collaborative Action Research

In past decades, action research had been viewed as being the idea of each individual teacher conducting research in his/her own classroom simply as a single individual. Recently, a new direction of action research has taken place to make it more collaboration between teachers from the same workplace or between teachers and university researchers (Zuber-Skerritt, 1996). Winter (1996) states collaboration is not just the diversity of people involved in the research but also the different points of view that each participant contributes in order to understand the situation. The diverse viewpoints provide the opportunity to collect rich resources rather than to make consensuses on diverse points of view in collaboration. The action research cycles: planning, acting, observing, and reflecting are laid out in the process of developing teaching. Collaboration is the process of planning, and reflecting among teachers and researchers, whereas acting, and observing processes are left for individual implementation in the classroom (Carr and Kemmis, 1986 cited in Feldman, 1993).

There are two different forms of collaborative action research. The first is classroom action research in which an effort is made to solve the same problem that is occurring in different classroom settings. These teachers from the same grade level or department work collaboratively to overcome their common problem. Another form of collaborative action research is the bridge relationship between university researchers and school teachers. In this type of action research the research itself put emphasis upon issues that are of interest to both the university and the school partners (McLaughlin *et al.*, 1995; Feldman, 1996; Raymond and Leinenbach, 2000;

Capobianco, 2002; Christensen, 2005). Some models involve a university researcher as a facilitator and teachers in the roles of collaborators. The second type of action research is the basis for this study in that a university researcher works collaboratively with a group of in-service Geology teachers from three Bangkok public schools.

A study by Feldman (1993) of a group of physics teachers engaged in the Physics Teachers Action Research Group (PTARG) performed a collaborative action research called “enhanced normal practice”, where teachers engaged collaboratively in action research through three mechanisms: anecdote-telling, the trying out of ideas, and systematic inquiry. Hsiung, Chen and Wang, (1990) study stated that utilizing the collaborative action research is a way to develop integration for students in learning geology. Collaborative action research is viewed as the opportunity for in-service teachers and university researchers to work together in order to systematically inquire about the effects of potential practice in Geology. McLaughlin *et al.* (1995) created connections among two university researchers and four school teachers to settle on two research problems; what do students believe they are learning and How do they learn, within and outside of the school? The research team conducted the study over an entire school year and collected data from: a series of formal interviews of students, a year-end written survey completed by each student, informal conversations with students, observations in classrooms, and so on. The research team collaboratively reflected upon what they learned about the students and teaching, and how to best carry out the action research.

Summary of Collaborative Action Research in the Study

Collaborative action research in this study is much like the work of Feldman (1996) and Copobianco (2002). The collaborative action research approach used in this study is based on a systematically framework inquiry of the teachers on their practices. Individual and collective inquiry is involved as a way to seek out anticipated teaching practices to change or improve based upon the needs of the teachers involved. The teachers are actively involved as researchers and they use their knowledge base and expertise to reflect, and modify their lesson plans and their own practices. In this study, the researcher depends heavily on the traditional model of the four step cycles of planning, acting, observing, and reflecting. The researcher talks in more detail about the action research model used in the CAR meetings (refer to chapter 3). In the first CAR meeting, the researcher started off by stating to the participants that she was a member of the team, explained the research method and made the teachers aware of the possibilities for change in their performances. Although there are a number of models for doing action research, this study strongly encourages teachers to use the collaborative action research model. Collaborative action research is carried out by a group of teachers that come together to solve common problems, consult with one another, create change, and accomplish some shared goals for improving their own practices (Feldman, 1996). In this manner, it refers to a group of teachers working together without direct involvement in or based upon directions from a university researcher (Capobianco, 2002). In this research, group members are assumed to have an active role and be completely involved. The group meetings are organized to facilitate collective learning for all but they are empowered with the right to outline and change their teaching practices as they relate to their own individual school's curriculum and their teaching situation.

CHAPTER III

METHODOLOGY AND METHOD

Introduction

This chapter addresses the features of a qualitative study and the interpretive approach as the theoretical framework for this research. Descriptions of the multiple sources of data used in the study which include: classroom observations, interviews, group meetings, and/or documents and the methods used to analyze the data can be found in this chapter. The information regarding the context in which the study takes place such as the school setting, students, and the other participants involved is provided as well. Procedures and timelines of the study are clarified and the final section of the chapter presents the evidence of the trustworthiness of the study and the ethical issues involved in conducting research.

The Qualitative Study

The purpose of this study is two-fold, first to examine teachers' teaching practices in a classroom setting and then to examine through an ongoing process, the changes their teaching practices undergo during the length of the study. Therefore, the distinct characteristics of a qualitative study serve the value of this study best. Although, there is no single, coherent set of characteristics of a qualitative study, there are a number of different sets of characteristics. Generally a qualitative study refers to a way to approach inductively and holistically an understanding of human experiences in a real-life situation and to construct meaning in this context-specific setting as well (Marshall and Rossman, 2006). Understanding actions, thoughts, feelings, beliefs and values are all a part of interpreting meaning and thus a qualitative study focuses on a small number of participants such as the three teachers in this study (Maxwell, 1998) and researchers need to put themselves into the specific contexts or settings that they are studying (Stake, 1995; Maxwell, 1998). Unlike the traditional deductive approach to research, the emphasis of a qualitative study is on, moving from the specific to the general, or from the bottom up to construct understanding (Stake, 1995; Lichtman, 2006). Instead of generating or examining hypotheses or causes and effects, qualitative research intends to give a thick description in order to develop an understanding of specific phenomena and the interrelationships between them (Erickson, 1986; Stake, 1995; Patton, 2002; Lichtman, 2006). Qualitative study relies on multiple methods of data collection to establish holistic understandings that emerge from patterns found in a large amount of data (Creswell, 2002). This data involves people and is pertinent to specific situations and therefore everything that happens to the people in the setting matters to the researcher because qualitative research cannot eliminate the effects of people or settings in a study (Taylor and Bogdan, 1984).

In terms of the purpose for conducting action research, qualitative research can be useful for studying the process of improving teaching practices rather than determining the effectiveness of implementing an intervention program. Studying collaboration among teachers' in their working community is also suitable to the qualitative method because it pays attention to a particular context for a prolonged period of time while at the same time understanding the participants and the context itself (Maxwell, 1998). This study uses the qualitative research method to provide in-depth descriptions, understandings of the natural settings of the classroom practices, the meetings of the collaborative action group, and teachers' teaching practices. What occurs in this study's contexts is interpreted by the researcher to construct meaning and understanding based on the gathering of adequate data. There is no right or wrong way of interpreting the data, in contrast, multiple realities can emerge from what is seen and heard (Stake, 1995). Therefore, the researcher is the primary instrument of data collection and analysis (Litchman, 2006).

The Interpretive Approach

Research in education tends to make generalizations based upon what happened in the past, is happening in the present and then what may happen in the future. The purpose of such research has been about searching for characteristics, techniques or factors that produce effective teaching. When the study is finished they make assumptions that their findings could be made applicable to any teacher in any classroom and the results would be an effective teacher. However, interpretive research disagrees with this view and states that effective teaching depends on a particular and specific context involving known teachers and students rather than a set of generalized characteristics regarding nonspecific groups of teachers or students (Erickson, 1986). A qualitative study takes into account the contexts in which the study is occurring, the interpretive approach focuses on putting meaning to the events or actions that happen in the those contexts (Maxwell, 1998). Interpretive researchers do not abandon the relationship between a specific classroom and the larger social organization and culture in which the teachers and students are working in because these have an influence on the teachers' or students' activities (Gallagher, 1991; Borko, Whitcomb and Byrnes, 2008).

Typically interpretive research differs from other research in the natural and social sciences in terms of assumptions, intentions, and procedures (Gallagher, 1991). The intention of interpretive research is to help researchers to understand in-depth, teachers' actions and the knowledge, thoughts, beliefs, and values that lie behind those actions. Interpretive research focuses on the understanding of socio-cultural processes that occur in natural settings (Borko *et al.*, 2008) in the way that teachers make sense out of them and give meaning to the social interactions that occur in their daily lives of teaching and learning. Not only does the interpretive approach allow researchers to construct cultural knowledge about science teaching and the teachers teaching it, the teachers themselves are able to become more reflective about their own work and as a result manage their own teaching and learning as well (Erickson, 1986; Borko *et al.*, 2008). Gallagher (1991: 9) noted that "interpretive research seeks to improve teaching by helping teachers (and the researcher) better understand the nature of their work and the meaning they give to it. In the same manner, interpretive research has given much attention to the study of teachers' thinking in recent years."

Thus, the interpretive approach regarding teaching seeks to understand what teachers do and why they do it that way; whereas, traditional research on teaching focuses more on the behaviors of teachers with less attention placed on the reasons that underlie these behaviors. It is a continuous process of learning about teachers' working lives and trying to make sense of the diversity and complexity of their stories (Hargreaves, 1994). In such learning, interpretive research allows researchers to ask and answer questions in a specific and detailed manner while at the same time giving descriptive information regarding the nature of the teachers' practices in their classrooms.

Regarding the methods of collecting data, the interpretive approach tries to capture what is happening during social interaction in a specific setting through field notes, audiotapes, videotapes, interviews, and reviewing artifacts such as teachers' journals. This way the researcher can identify educational settings that foster, shape, or constrain teacher learning (Borko *et al.*, 2008). To make for better understanding, the researcher needs to enter into long term relationships with the teachers for the purpose of learning about the manner and contexts in which the teachers do their work, how they think about it, and what "forces" influence their thoughts and actions, their personal and professional commitments, engagement with colleagues, as well as the context of their schools (Gallagher, 1991; Hargreaves, 1994). Moreover, they need to examine the meaning of the moments in which the actions actually occur. Natural settings can be used when researchers cannot create the same situation in an experimental condition. Rather than changing practices and ignoring the knowledge, beliefs, and values of experienced teachers, the interpretive approach understands the 'wisdom of practice' of teachers that exists in schools on a daily basis. More importantly, the variations and uniqueness of each school, teacher, or student are the key factors that researchers have to respect when individuals make decisions or find solution to a particular problem in their school.

The Research Design

The Case Studies

The definition of case studies varies with respect to the intentions of understanding. Stake (1995) identifies three different types of case studies: the intrinsic, the instrumental, and the collective. The intrinsic case study aims to learn about one particular case one is interested in. While the instrument case study is considered an instrument to achieve something rather than an understanding of a particular situation, or person. Rather than choosing one particular person, or organization, collective case studies are used to learn the coordination of each individual case. Yin (2003) identifies six different types of case studies which can be distinguished by two different foci. First, they can be divided into single- or multiple-case studies, and these can be exploratory (aiming to define questions, and hypothesizes or to determine designed research procedures), descriptive, or explanatory (causal).

The case study is a method of studying phenomenon that is indistinguishable from its context and is associated with the complex interactions that occur in varied situations (Cohen *et al*., 2000; Yin, 2003). To ensure the completeness of using case studies, there are three major features to include in the studies of this type: the richness of context, the use of multiple sources of evidence and rigorous analysis techniques (Yin, 2003). As a result, the approach of qualitative method involves a specific way of collecting, organizing, and analyzing data to gather comprehensive, systematic, and intensive information about each single case of interest (Stake, 1995; Patton, 2002).

The analysis of a case study should not be generalized to other cases in contrast the uniqueness of a particular case or intrinsic case can make it better understood (Stake, 1995). Case studies can be composed of a single participant or a group of several participants depending on what type of unit analysis researchers want to study. This study focuses on the unit of analysis as individual case studies which consisted of three individual participants. Cases were selected from their willingness to be involved in further study of the interesting characteristics that come out of teachers working in a group. Individual case studies were reported on using two major areas of data. The first involved personal information such as the teacher's educational background, school context, teaching experiences, and teaching perspectives. The other area of data involved observations of the teachers' classroom practices, interviews, their journal reflections, and other artifacts. All this data is recorded and reported upon regarding each individual case.

The Specific Context

Description of the Curriculum Context:

The Geology course is offered to students in grade levels, ranging from 10 to 12, depending on each school-based curriculum. This means that the Geology course can be developed and regulated by the teachers regarding the depth of the content they explore and the activities they use to do it. The National Science Curriculum Standards offers only a broad framework and therefore the course is strongly influenced by how the teachers' organize it in their different school settings in terms of grade level, content, time, and activities. The National Science Curriculum Standards (IPST, 2002) does give a broad framework for what content and process skills the students should have by the end of the highest grade in which they study. The geology content in the level standards for grades 10 to 12 are composed of (IPST, 2002, 2004b, 2005a):

1) Changes in the Geo-sphere
2) Geological phenomena and their importance to living things and the environment and their occurrences including earthquakes, volcanoes, and plate movement.
3) Fossils, rocks, and their stratifications
4) Age for the study of the Earth's history

Participants

Following qualitative research methods, the researcher focused on a small group in order to obtain greater descriptive information and develop an in-depth understanding of them and their situations. Thus the study's participants were three in-service teachers of Geology in the upper secondary level in three different public schools. They were all volunteers for the study (Patton, 2002). All three teachers were chosen based on their interest in participating in the study as indicated in a questionnaire developed by the researcher in a pilot study (Hanpipat and Roadrangka, in press). The questionnaire's purpose was to examine teachers' responses regarding their teaching of Geology in their current situation and the problems they have struggled with. The researcher sent out 36 questionnaires to different public high schools under the Bangkok Education Service Area 2 that was specific to Geology teachers in the upper secondary grade levels. The questionnaire contained a brief explanation of the larger study concerning professional development for Geology teachers and the teachers were asked if they would like to participate in this larger study. Once the teachers indicated yes, they were screened based upon their responses to what would be their motivation for being part of the larger study group. In the end three criteria were used for choosing the participants and they were as follows:

1) Teachers who were teaching Geology in the upper secondary levels in school located near to Kasetsart University and still under the Bangkok Educational Service Area 2.

2) The teachers were teaching Geology in both semesters and could participate in both phases of the study.

3) They showed a willingness to contribute to the profession by being open to classroom observations by the researcher, participate in follow-up interviews and be able to attend the CAR group meetings.

The participants selected provided a variety of views and backgrounds from which the researcher could draw data. Typically, each school that received the questionnaire had only one or two teachers assigned to the Geology course and thus all the participants ended up being from different schools. They came from diverse backgrounds both academically especially in their university training and in how they worked in their individual school situations. All three participants were female and to protect their privacy they were given pseudonyms, Ms.Pimpon, Ms.Kanokpon, and Ms.Sunee. The following section and Table 3.1 describes the teachers' education backgrounds and their school situations.

Teachers' Background

1) Ms.Pimpon

Ms.Pimpon, who was 56 years of age at the time of the study, has a Bachelor's degree of Science in Geography and a Master of Education degree in Educational Administration and has been teaching Science for 32 years. Since 2002, she has been teaching Geology and Astronomy (sub-strands 6 and 7) and is the only teacher in the school with the responsibility of teaching these topics in the upper secondary levels something for which she volunteered to do even though she did not have a strong background in Geology. It is for this reason that she attended several workshops and took courses related to the area of Geology during school holidays.

The workshops and courses covered theoretical knowledge related to Geology as well as provided her with opportunities for practical field experiences. The following is a list of some of the institutions in which Ms.Pimpon attended upgrading activities in Geology: The Institute for the Promotion of Teaching Science and Technology, IPST; the Department of Geology, Faculty of Science, Chulalongkon University; the Department of Physics, Faculty of Science, Mahidol University; and Department of Mineral Resources in Ministry of Natural Resources and Environment. The many workshops she attended covered topics such as: designing lesson plans, making teaching and learning materials, and knowledge directly related to the field of Geology. On several occasions, she participated in field trips that allowed her to collect real specimens such as volcanic rocks and fossils. It would be fair to conclude then that Ms.Pimpon possesses a strong content background in Geology. It was for this reason that the she was invited by The Institute for the Promotion of Teaching Science and Technology, IPST to be a member of the committee that is responsible for developing Science standards and textbooks. Her area of expertise on the committee is Geology and Astronomy (sub-strands 6 and 7).

2) Ms.Kanokpon

Ms.Kanokpon is 45 years old and has a Bachelor's degree of Education in general science. She has been a science teacher for 20 years. In years previous she taught science in the lower secondary levels and a fundamental science course to non-science streamed students in the upper secondary levels. For seven years now, she has been teaching Geology and Astronomy in the upper secondary levels. She is solely responsible for the teaching of these two subjects in the upper secondary levels to both science and non-science students. She teaches these two subject areas even though it is not her area of expertise and she has never attended any courses or workshops related to Geology or Astronomy since taking on this responsibility.

3) Ms.Sunee

Ms.Sunee was a new participant in this research because one of the original participants that the researcher worked with in the first semester dropped out due to personal reasons. Ms.Sunee entered the study with intentions to improve her skills in teaching Geology. Ms.Sunee was 45 years old at the time of the study. She has a Bachelor of Education with a major in general science teaching and a Masters of Education in science teaching. Before coming to Laliya School, she had been a science teacher at a local public school in Mukdaharn for six years. She has been teaching at Laliya School since 1990.

Ms.Sunee used to teach the general science course in the lower secondary levels, physical-biological science for non-science oriented students, and Chemistry and Biology for science oriented students in the upper secondary levels. About a year ago, she replaced a colleague who had taught the sub-strand 6 and 7 topics, Earth, Astronomy and Space. She did not just teach only geology but also general science and science projects in the lower secondary levels and Physics (as a fundamental) for the upper secondary levels. Additionally she also had a number of miscellaneous school activities assigned to her that included girl scouts for 2 hours per week a science club for 2 hours a week and she worked on creating a school policy unit after hours.

School Backgrounds

The study was conducted in three public high schools that fall under the Bangkok Education Service Area 2 situated in middle class suburban communities. The rationales for choosing those particular schools included the fact that the researcher had easy access to their locations, everyone could more easily attend group meetings. Again the schools were give pseudonyms, Warin, Isara, and Laliya to protect their privacy. The context of the three schools and the background of the students involved are provided in the following section and in Table 3.1:

1) Warin School

Warin School has been open since 1971 and was created by combining a number of smaller schools and has grown from a student population of 1000 students to the over 4000 students it now has. Its vision is to focus on science and to encourage its students to develop thinking skills, learn problem solving and creativity. The school also aims to make its students posses a proper attitude, be moral and ethically sound towards science, technology and the environment. All this has given the school a reputation of being academically high in its students' achievement levels.

In more detail at the time of this study, there were 4,961 students enrolled in the school 2,375 of them boys and 2,586 of them girls. Of the larger total, 2,614 were in the lower secondary levels and 2,347 were in the upper secondary levels. These students were all divided into 16 classes at both levels with the number of students in one class ranging from 48-55. At the upper secondary level, the students are offered a variety of optional study programs which they can select based upon their interests and their academic aptitude. Some of these options include Science and Mathematics, Engineering and Architecture, Liberal Arts, and the Gifted program (for students who are granted IPST scholarships). The total teaching staff was 232, 43 of which have Masters Degrees and the rest Bachelor Degrees. The science department consisted of 39 teachers, 9 of which had Masters Degrees and the rest Bachelor Degrees.

The school year is divided into two semesters each lasting 18 weeks, 16 weeks to cover all the content and two to give mid-term and final exams. A teaching period is 50 minutes long, but most Geology classes are double periods and thus are 100 minutes long and the students have one of these per week.

This particular school is located in an urban area of the city and is surrounded by the local community and a university. The majority of the students are from families with average or high socio-economic backgrounds who are employed by the government, work in the private sector or own their own businesses.

The Students' Background

According to the Ordinary National Education Test (ONET) for students in grade 12 (Mathayom 6) in the 2007 academic year the students in this school ranked academically in second place out of all the schools, 52, in the Bangkok Educational Service, Area 2. Their average score out of six subject areas Thai language, Social Sciences, English language, Mathematics, Science, Health Science and Arts, and Occupation and Technology was 53.02 percent. Average scores for Science were 52.16 which were quite high compared to the nationwide average score of 34.62.

2) Isara School

Isara School was established in 1992 and is the youngest school in the study. The school is located in a suburban area in Bangkok and is surrounded by small villages and agricultural fields. Most of the students are from families with medium or low socio-economic backgrounds with their occupations primarily being farmers and the owner of small businesses like vendors in markets. The goal of the school is to give their students a good academic background in order to produce well educated, moral and ethically responsible individuals. The school administration provides services to its stakeholders in order to constantly improve the academics of the school. There were at the time of this study, 2,612 students enrolled in the school 1,229 of them boys and 1,383 of them girls. Of the larger total, 1,747 were in the lower secondary levels and 865 were in the upper secondary levels. There were 58 classes of students, 24 classes in the upper secondary, 8 classes per level with 35-40 students per class and 12 classes in the lower secondary levels except for grade 9 (Mathayom 3) with only 10 classes with 48-53 students per class. There were 84 teachers in all departments in the schools (23 teachers with Master degree and 61 teachers with Bachelor's degree). According to science department, there were 14 science teachers. One semester lasts for 18 weeks, comprising 16 weeks of teaching and learning and the rest for mid-term and final examinations. A teaching period lasted for 50 minutes. A teaching geology period lasted for 100 minutes (2 consecutive periods) per week.

The Students' Background

According to the Ordinary National Education Test (ONET) for students in grade 12 (Mathayom 6) in the 2007 academic year, this school's students' scores ranked 29th out of the 52 schools under the Bangkok Educational Service, Area 2. Their average score from the six subjects: Thai language, Social Sciences, English language, Mathematics, Science, Health Science and Arts, and Occupation and Technology was 43.38 percent. Average scores for Science were 37.91 which were slightly high compared to the nationwide average score of 34.62.

3) Laliya School

Laliya School is located in an urban area in Bangkok and had at the time of this study, a total student population of 2,630, 1,288 of them boys and 1,342 of them girls. Of the larger total, 1,783 were in the lower secondary levels and 847 were in the upper secondary levels. There were 61 classes of students, 24 classes in the upper secondary, 8 classes per level. Laliya School main aim is develop learners that behave sensibly and morally as members of society and they put emphasis on the idea that society also includes the global world and that education should be a life-long pursuit. There were 111 teachers in all departments in the schools, 37 with Master Degrees and 74 with Bachelor Degrees. Laliya School offers 5 optional study programs for the upper secondary students; Science and Mathematics, English and Mathematics, English, French, Chinese or Japanese, and Computer Technology.

The school is surrounded by a number of villages, large companies, business areas and some inner city. The majority of the students were from middle and lower class families with over a half of their parents involved in jobs as vendors, government employees, employees of the local companies and some involved in manufacturing. The students in the school and the school itself are seen as having problems regarding teaching situations and not having enough resources to provide effective education for all its stakeholders. There were 18 weeks in a semester; 16 weeks for teaching and 2 weeks for examination sessions and a period was 50 minutes long. Geology was taught 3 periods a week, a single period and a double period for a total of 150 minutes.

The Students' Background

According to the Ordinary National Education Test (ONET) for students in grade 12 (Mathayom 6) in the 2007 academic year, this school's students' scores ranked 26th out of the 52 schools under the Bangkok Educational Service, Area 2. Their average score from the six subjects: Thai language, Social Sciences, English language, Mathematics, Science, Health Science and Arts, and Occupation and Technology was 43.89 percent. Average scores for Science were 36.01 which were slightly high compared to the nationwide average score of 34.62.

Table 3.1 Overview of Participants' Information and School's Context

Information	Ms. Pimpon (Warin School)	Ms. Kanokpon (Isara School)	Ms. Sunee (Laliya School)
Educational background	-Bachelor's Degree of Science (B.Sc.) (Teaching Geography) -Masters Degree of Education (M.Ed.) (Educational Administration)	-Bachelor's Degree of Education (B.Ed.) (Teaching General Science)	- Bachelor's Degree of Education (B.Ed.) (Teaching General Science) - Masters Degree of Education (M.Ed.) (Teaching Science)
Years of being a science teacher	32	24	24
Years of teaching Geology	5	7	1
Numbers of workshops attended related to Geology	-Faculty of science, Chulalongkon University and Mahidol University -IPST -Department of Mineral Resources, Ministry of Natural Resources and Environment	None	None
Other subjects they taught along with Geology	None	Physical Science (upper secondary levels)	-General Science (lower secondary levels) -Science Project (lower secondary levels) -Physics (basic)
Numbers of classes they taught	16 (8 classes per semester)	8 (4 classes per semester)	5 (Only non-science oriented)

Table 3.1 (Continued)

Information	Ms. Pimpon (Warin)	Ms. Kanokpon (Isara)	Ms. Sunee (Laliya)
School context			
-Numbers of students	Over 4,900 students	Over 2,600 students	Over 2,700 students
-Numbers of students per class	49	37	36
-Students' parent financial status	Average to High	Average	Average to Low
-Ranking in ONET (out of 52) (In Bangkok, Area 2), 2007	2nd	29th	26th

Procedures and Timeline of the Study

This section provides details regarding the procedures of the study which consists of two phases: the exploratory phase of current teachers' teaching practices, and the design and development phase through Collaborative Action Research. The first phase involves discussing and exploring in-depth the teachers' current teaching practices of Geology in the upper secondary levels through classroom observations, semi-structured interviewing protocols, and other related documents such as lesson plans, student worksheets, or teachers' assessment and evaluation sheets. The first phase of the study began in the first semester, July to September, 2008. However, data collection did not occur at the same time in each school because at the individual school level the Geology curriculum was organized in different sequences.

In the second phase, the Collaborative Action Research group (CAR) was established as the place for sharing teachers' experiences and knowledge of teaching Geology, for planning an integrated curriculum, and reflecting upon implementing lesson plans. The CAR group meetings took place in the second semester from November, 2008 until January, 2009. In addition to the CAR group meetings, the researcher concurrently conducted classroom observations when the participants were implementing the integrated curriculum and held post-class interviews to obtain reflections after the implementation. Information regarding the data collection and timelines are addressed in Table 3.2.

Methods of Collecting Data

To answer the two research questions, the researcher used multiple sources of data in order to provide a comprehensive perspective of the study. This section describes the objectives of all the instruments and methods of data gathering in the two phases of the study. The instruments and methods of data gathering used in this study consisted of:

1) An interview protocol to determine current teachers' teaching practices (the first phase) and an interview protocol of teachers' responses on implementing an integrated curriculum (in the second semester)

2) Classroom observations with video recordings and the researcher field notes

3) The Collaborative Action Research (CAR) group meetings with video recordings

4) An interview protocol to determine current teachers' teaching practices (the first phase) and an interview protocol of teachers' responses on implementing an integrated curriculum (in the second semester)

5) Classroom observations with video recordings and the researcher field notes

6) The Collaborative Action Research (CAR) group meetings with video recordings

7) Document analysis

Table 3.2 Data Collection and Timeline

Phases of the study and the Research Question	Participant	Methods of collecting data	Timeline
First Phase *RQ 1*: How do geology teachers' actual teaching practices compare to the integrated curriculum's suggested teaching practices?	Three geology teachers from 3 different public schools	1.Semi-structured interviews 2.Direct observation (video recording) 3. Document analysis (teachers' lesson plans, students' worksheets)	July-September 2008 (the first semester, academic year 2008)
Second Phase *RQ 2:* How do Geology teachers change their teaching practices after participating in the collaborative action research group (CAR)?	Three geology teachers from 3 different public schools (with the science educator and the researcher in the CAR group meetings)	Four 3 hour sessions of CAR group meetings: received data from: -Video recordings -Teachers' documents (lesson plans, students' worksheets, reading materials, questions)	Once a month throughout November 2008-January 2009 (the second semester, academic year 2008)
	Three geology teachers from 3 different public schools	Individual implementation of an integrated curriculum received data from: -Direct observation (video recordings) -Post-class interviews	Once a week from late December 2008-early February 2009 (the second semester, academic year 2008)

Since each method of data collection has both strengths and weaknesses the methods overlap and each provides information about both research questions. From combining these methods, the researcher was able to validate and cross-check the findings (Patton, 2002).

The Semi-Structured Interviews

Interviewing is a method used to obtain individual perspectives or reflections and explore feelings and thoughts about issues (Patton, 2002). The researcher needs to be careful when using interview data because it might be limited by the emotional state of the interviewee (e.g. anger, anxiety) when the interview is taking place. Further, "the quality of the information obtained during an interview is largely dependent on the interviewer" (Patton, 2002: 341). The interviews in this study were not too structured as this could limit the interaction between the persons involved. A more relaxed or semi-structured format was used in order to make the interviewee more comfortable responding to the open-ended questions of the interviewer. This type of interview also allows for a more open flow of conversation which can be diverted away from the list of prepared questions and allow for the divulgence of even more information. Patton (2002) called this "the interview guide" and it provides an opportunity for the researcher to explore, probe, and ask questions spontaneously. The Semi-structured interview format was used to understand the teachers' backgrounds in their different school contexts, the teachers' reflections on participating in the collaborative action research group, and their reflections after implementing the integrated curriculum. The interview schedule is addressed in Appendix. All of these interviews were one-on-one interviews with the individual teachers. The information gathered from the semi-structure interview certainly fulfilled any understanding of events, behaviors, interactions, or even artifacts that were shared during the observation.

In the first phase, an interview protocol was developed for understanding the teachers' practices. The content of the interview protocols included teaching methods, the uses of teaching and learning materials, assessment and evaluation techniques, and the integrated curriculum. Teachers were asked to describe their most commonly used teaching methods particularly when teaching Geology, a variety of uses they make of their teaching and learning materials or other resources existing in their school's facilities, and any different types of assessment and evaluation techniques they use regarding the students' learning. Teachers were also asked to explain what they thought about using an integrated curriculum in their classroom. This interview lasted approximately 30 minutes depending upon the teacher's eagerness to reflect or talk about their teaching practices. In the second phase, several interviews took place to explore the teachers' feedback on their teaching practices involving the integrated curriculum and they were conducted at then end of each lesson. Teachers were asked to give responses based upon any expected or unexpected situations that arose during the lesson, whether it was suitable or not for the students in their classes, problems that might have occurred and how to solve these problems before the next class and any other feedback they felt important to share regarding the integration. These interviews lasted approximately 30 minutes.

All the interviews were audio-taped and in order to analyze them they were transcribed verbatim. The information of the teachers such as their pseudonym and date of the interview were included in the transcripts. The transcripts of the teachers' responses were classified into categories and then they were compared and contrasted to show the differences and similarities of the teachers' responses.

Classroom Observations

Observation is a fundamental and critical method in all qualitative inquiry. It is used to discover the complex interactions in natural social settings and make a recording of events, behaviors, interactions, body languages and artifacts (Marshall and Rossman, 1995). In this study, classroom observation was considered to be a vital source of data to understand the teachers' teaching practices in the classroom in both phases of the study. The researcher tried to observe as many Geology classes as possible for each teacher and immersed herself in their classrooms starting in the first semester in order to build rapport. The teachers thus felt comfortable teaching in front of her which was important for truthful observation results.

The researcher remained a passive participant and did not interact with the teachers or students during the lessons (Patton, 1990). The researcher used a video tape to record the details of the lesson and to be able to observe the teacher, students, the atmosphere and interactions that occurred. By doing this the researcher had a permanent observation of the lesson and could make her own field notes which would be an essential source for reminding her of interesting events that might have happened, a diagram of the classroom set-up, the date and time of the observation, interactions that occurred between the teachers and students and the students between themselves, how well they behaved and paid attention in class and the emotion of the teacher. During the analysis process, all the data collected from direct observations were transcribed verbatim and the researcher's field notes were coded and categorized to develop the themes that provided the general views of the teachers' practices. These themes were refined to explore patterns of teaching practices among the three teachers.

The Collaborative Action Research (CAR) Group Meetings

The three participating teachers, a science educators and a researcher created and were members of the CAR group and collaboration through the group meetings occurred in the second semester of the 2008 academic year. There were four group meetings, roughly once a month. Unfortunately, some teachers were not always able to attend every meeting, but each time at least two teachers attended. This study attempts to understand the interaction between teachers in a group, thus, the researcher needed to be part of the group. Building trust and respect between the teachers and the researcher is necessary in order to have good relationships develop between them (Brickhouse, 1991). When the researcher maintains a positive relationship with the other members of the group, in this case the teachers, then they all feel comfortable to speak honestly about what they think and thus the information they are sharing is much more dependable and constructive.

Each CAR group meeting had different goals regarding collaboration and activities as described in the follow section. The first two meetings focused on the planning stage of the action research and the last two meeting focused on implementation and reflection. Descriptions of all the CAR group meetings are reviewed in the following section and in Table 3.3

Description of the CAR Group Meetings:

1.The First meeting

The first meeting was the place where the teachers started to build their relationships and it was at this meeting where they started to learn from each other regarding their teaching practices as they related to Geology. This meeting gave the teachers an opportunity to share teaching experiences, difficulties, and contexts of their schools and students. They discussed the research and how they were going to achieve the goal of teaching Geology using an integrated curriculum. At the end of this meeting, the researcher discussed her role in the study, explained the data collection methods and the timeline. The aims and procedures of the first meetings were:

1) Focus on the essences of Thai education as it relates to the Basic Education Curriculum and its National Science Curriculum Standards. Raise teachers' awareness of educational goals to make them more aware of good teaching practices. The researcher did not take a lead role in this, but instead let the teachers discuss and raise educational issues themselves regarding educational reform outlined in the National Education Act B.E. 2542 (1999), Basic Education Curriculum B.E. 2544 (2001), and the National Science Curriculum Standards B.E. 2544 (2002) instead. All of these are legitimate documents upon which to base Thai education and thus discussion rose regarding their goals and values and how to meet them as outlined in the documents. This activity's aim was to make teachers realize their roles and the value of themselves. This activity gave the group the opportunity to critique the goals of Thai education, discussing why they are important and how to reach them.

2) Clarifying the researcher's role and teachers' role in this study. The researcher serves as a facilitator who will help them with teaching resources, ideas and content knowledge when asked. She made it clear that she was not an expert, but her role was to support them and be part of the group. The meetings were a place for the teachers to share their ideas and experiences and perform as researchers themselves by examining their own problems or new practices (Capobianco and Joyal,

2008). This session included information about the purposes and processes involved in conducting action research and an overview of the teachers' roles and responsibilities when participating in the collaborative action research in the following semester. The researcher will take part in discussions with the teachers about how to implement an integrated curriculum and challenge the teachers to improve their own practices, providing guidance as needed. At the starting point of the study the teachers might feel reluctant and uncomfortable with their professional and intellectual security (Evans, 1996) and thus the researcher clarifies brief details of the concepts and procedures of the study to make sure the teachers understand their roles. Consideration of the teachers' workload and responsibilities in the school is something the researcher has to keep in mind when supporting the teachers and make sure the plan is flexible when it comes time to scheduling meetings, interviews, or observations.

The teachers' role in the study is to investigate ways to improve their teaching practices through planning lessons, taking action, and reflecting on their practices. Individual teachers identify problem areas they would like to improve upon and within the meetings share their ideas and listen to what their colleagues might respond with. The researcher may have their own interests or agenda for doing the study and thus they, along with the teachers, must be open about their reasons for being involved in the study and this should take place at the beginning.Teachers can take action to improve their teaching practices when the researcher acts as a facilitator to help the teachers get where they want to be and not where the researcher wants them to be (Kosmidou and Usher, 1991). According to the basic principles of action research, when teachers solve their own problems to improve their teaching practices that fit their teaching context then success is more of a reality (Hargreaves, 1994).

3) Sharing teachers' background and school context. In order to get a good view of the participants and their school situations the teachers in the first meeting engaged in discussion regarding their educational backgrounds, school contexts, students' context, school policies, and school-based science/Geology curriculum in the upper secondary grade levels. This discussion provided all the participants with a rich understanding of the background of the individual teachers and their teaching

situations. Individual teachers shared their problems regarding the teaching of Geology in their own situations and brought examples of their lesson plans to provide a better sense of their teaching practices.

4) Group discussion is used to critique the characteristics of the Geology content itself as it contains knowledge from several areas of science such as physics, biology, and chemistry. This process involves helping the teachers rethink the connections of these other sciences' concepts with those of Geology by helping them recognize the essence of integration in teaching and learning geology. The research framework of the integrated curriculum was introduced to the teachers and an example of an integrated curriculum based upon Geology content was demonstrated later on. Both the research framework and the example of the integrated curriculum were pre-approved by the science educator after much discussion and revision. The researcher gave an overview of the integrated curriculum to help the teachers understand the value of using an integrated curriculum when teaching Geology and to help them recognize the interrelationships of other science content in the Geology content. To show how to put integration into practice, example lessons plans were created such as one that discussed the topic of tectonic plate movement and the processes which cause this movement. This particular sample lesson contained suggested teaching practices, the standards being met, student learning outcomes, lesson objectives, lesson activities, assessment and evaluation procedures, and all student handouts both worksheet and lab hand outs. The teachers were given it ahead of time in order to be able to review and reflect upon it.

5) To develop the teachers' lesson plans, this study was designed to give the teachers the freedom to create them with guidance and suggestions from the science educator and the researcher. This was the starting point for teachers to begin to understand themselves as being good teachers and how they could reach their goal. Individual teachers were given time to plan their integrated curriculum after the meeting with collaboration from the researcher during school breaks or school days. They were asked to share their lessons in the second group meeting. To help teachers view Geology as interrelating with other science contents, teachers were given the opportunity to discuss and to analyze the Geology content together. This activity

could also be a guideline for teachers to use in the planning stage. Teachers were required to finish at least one lesson plan on the first chapter about the Earth's structure so they could bring it to the next meeting for discussion.

2. The Second Meeting

The second meeting aimed to provide the teachers with opportunities to learn individually or collectively with others. The topic of the lesson plan to be discussed at this meeting had already been assigned, the first chapter on the Earth's structure. The second meeting devoted time for the teachers to share their ideas on how to design lesson plans that integrate concepts from other areas of science into the Geological content that discuss this topic. Their lesson plans had to consider their individual school-based curriculums and their own teaching situations.

Individual teachers presented their designed lesson plans to the group members. Descriptions of activities, questions, the students' worksheets, or assessment and evaluation techniques were provided to get a sense of their practices. The group members were asked to reflect and to make suggestions regarding the individual teacher's lesson plans. Teachers learned how to improve their lessons during this valuable discussion time. This process involves helping them to seek new routes to transforming their lesson plans and practices when they implement them in class.

3. The Third and the Fourth CAR Group Meeting (Implementation and Reflection)

The third CAR group meeting was the first time that teachers reflected on their teaching practices after implementing their lesson plans in their own classrooms. Teachers were asked to share their experiences, problems, and students' responses. The fourth meeting was mainly for teachers to exchange their experiences, responses, and problems regarding their teaching practices after teaching a particular lesson. This meeting was not just for the researcher to hear all this information, but also an opportunity for each participant to reflect upon their colleagues responses and perhaps contribute further reflections. Once the group meetings occurred the researcher was able to understand a variety of perspectives from where the group and the individual teachers are coming from thinking wise. They discussed and analyzed each problem and proposed some recommendations to solve the problems using their teaching experiences.

Document Analysis

The type of data collection methods used in this study provides information beyond other methods which might be unable to directly observe, interview, or appear in journals (Patton, 2002). The researcher analyzed teaching artifacts that were created to be used in the classrooms and collected all the integrated curricula, reading materials, students' worksheets or questions and lab sheets being used in the classroom. All of these were an alternative data source used to better understand the teachers' thinking patterns.

Data analysis

The Inductive Analysis Approach

Inductive analysis evolves from the specific categories of meaning inductively derived from the data to the general understandings (Maykut and Morehouse, 1994). In other words, categories are not predetermined at the outset of the study rather they emerge from the data itself. Beginning with the gathering of great amounts of data, the researcher first seek out tentative categories or codes and rename them to more precisely reflect the nature of the data collected. The categories need evidence to support them (Merriam, 2009). Thus the researcher moves to more general statements, questions or themes once specifics are found in the data (Lichtman, 2006). Inductive analysis is employed to allow important information to emerge from patterns found in the cases (Patton, 2002). The research then seeks to make interrelationships among those patterns and dimensions that occur in the information.

In this research, data from audiotapes and videotapes of the semi-structured interviews, classroom observations and group meetings were transcribed verbatim. Further data from document analysis of the teachers' artifacts such as lesson plans, students' worksheets, or reading materials were analyzed to seek relationship patterns with other sources of evidence. All the data was coded to enable the researcher to generate separate categories which would then be placed in the area dealing with the specific research question as listed below.

Table 3.3 Overview of the Collaborative Action Research (CAR) Group Meetings Structure and Content

Topics of Discussion			
Group Meeting I (Nov 27, 2008)	**Group Meeting II (Dec 13, 2008)**	**Group Meeting III (Dec, 28 2008)**	**Group Meeting IV (Jan 24, 2009)**
-To share teaching experiences, school context, students	-To exchange the teachers' ideas regarding designing lesson plans involving an integrated curriculum	-To exchange teachers' ideas of designing lesson plans involving an integrated curriculum	-To exchange teachers' ideas regarding designing lesson plans involving an integrated curriculum
-To Introduce an integrated curriculum to the teachers	-To share individual lesson plans	-To share individual lesson plans	-To share individual lesson plans
-To give an example of a lesson involving an integrated curriculum	-To make comments and suggestions on the designed lesson plans	-To make comments and suggestions on the designed lesson plans	-To make comments and suggestions on the designed lesson plans
-To clarify the researcher's role, data collection methods, and timeline of the study		-To share responses about their teaching practices after implementing each lesson plan	-To share responses about their teaching practices after implementing each lesson plan
-To analyze the science content knowledge underpinning the Geology content		-To discuss ways to resolve problems that emerged from the implementation	- To discuss ways to resolve problems that emerged from the implementation

1) Categories identifying current teachers' teaching practices were placed into four dimensions; teaching and learning processes, the use of teaching and learning materials, assessment and evaluation techniques, and using an integrated curriculum.

2) Categories identifying the changes in teachers' teaching practices after developing and implementing an integrated curriculum identified teachers' learning based upon their participation in the collaborative action research group (CAR).

Relationships and patterns of all the categories were interpreted and themes or general statements were created to represent the overall perspectives of the data. As this study is based on a multiple case studies design, there are two stages of analysis, one involving a within-case analysis and the other a cross-case analysis (Merriam, 2009). A case analysis looks for intensive comprehension of each case itself. Analyzing data begins with the construction of categories and themes from examining independently the individual cases. When the initial stage of understanding an individual case is completed it is followed by a cross-case analysis to search out patterns and themes that occur that are present in all three cases and are then compared and contrasted using the inductive approach. Several case studies are then compared and contrasted and the credibility of the overall findings will depend on the quality of the individual case studies (Patton, 2002; Merriam, 2009).

Judging Quality of the Study: Trustworthiness

The hallmark of any good research that is worth the attention of an audience is one that follows a systematic and rigorous process (Lincoln and Guba, 1985; Stringer, 2007). The rigorous process of quantitative research is stressed on the criteria in terms of 'internal validity', 'external validity', 'reliability', and 'objectivity' (Lincoln and Guba, 1985), but interpretive research, being essentially qualitative, uses a different set of criteria. Rigor in qualitative research is based on the "trustworthiness" of the outcomes of the research which can be assessed through procedures (Lincoln and Guba, 1985).

Credibility is a fundamental criterion of qualitative research that parallels internal validity in conventional research. Mertens (2005: 254) believes that "the credibility test asks if there is a correspondence between the way the respondents actually perceive social constructs and the way the researcher portrays their viewpoints". To enhance the trustworthiness of the study, the researcher needs to use a variety of research strategies and provide evidence from multiple sources to ensure the credibility of the research.

Long-term Engagement and Persistent Observation

Long-term and persistent observation is important when gathering data and thus the researcher needs to be in the field until the researcher is confidence that themes and examples are repeating. In this study, the researcher spent two semesters working with the participants observing, interviewing, and participating in informal discussions in order to intensively explore and understand the teaching practices of the participants. This was a way to develop the credibility of the study as well as to obtain insight into and understanding of the teachers' teaching practices. It also gave the researcher the opportunity to observe participants during events and interactions that occurred and during double periods in order to identify important issues that could pertain to the study.

Triangulation

Triangulation is defined as the use of two or more methods of data collection in a study (Cohen *et al.*, 2000). Triangulation is another method to develop credibility of a study. Information about teachers' teaching practices is collected from multiple sources of data from different means and locations such as classroom observation, interviews, document analysis, and the discourse in the CAR group meetings. The understanding regarding teachers' beliefs on teaching and learning Geology emerged from the evidence such as pedagogy in classroom, perspectives on teaching from interviews, or outlines of activities in teachers' lesson plans. These means aimed to clarify a particular situation, phenomenon, or action in the classroom practices by seeking a consistency in the evidence.

Member Checks

Documents for building themes or evidence from data collection such as interviews, classroom observation were reviewed by the teachers to verify meaning and clarify intensive details regarding their teaching practices. Mertens (2005) notes that member checks is the most important criterion in establishing credibility. This method permits participants to review and verify any meaning that the researcher interprets and constructs from the data. By doing these member checks, the researcher can be assured that the constructed interpretation truly represents the whole perspectives or experiences of the participants. In addition, the participants are allowed to give more clarification or provide more detailed information of their perspectives to achieve better understanding as well (Stringer, 2007). In this study, the researcher asked the participants to validate the interpretations or data from multiple sources. The participants were given the opportunity to add more details or to dispute any of the interpretations.

Thick Description of the Data

The study provided details of the context of the participants, schools, and students to its audience in order to give an overall general picture of the settings. The details of each participant (including their teaching experiences, or educational backgrounds and classroom contexts) were described. Moreover, school policies, or factors affecting their teaching practices such as the pressure to maintain a school’s reputation in the community were described for the audience. Guba and Lincoln (1989) suggested that thick description helps audiences to determine the degree of it being applicable to the outcomes of a particular study or possibly being relevant to their own situation or its transferability. Qualitative research typically studies small numbers of participants or a specific context and it could not be representative of a large population or situations. As a result, the researcher must provide sufficient details known as the “thick description” of time, place, activities, events, contexts, or cultures of the study. The description of these idiosyncratic circumstances enables the audience to make judgments themselves (Mertens, 2005; Stringer, 2007). This criterion is parallel to reliability in a positivist paradigm (Guba and Lincoln, 1985).

Auditing

Auditing could be used to track the research's method and procedures of the study (Seale, 1999). For example, evidence from multiple sources is presented as statements from interviews or as discourse from classroom interactions between teachers and students. Data obtained from these settings were transcribed and interpreted by the researcher. Subsequently, meaning from the teachers' actions and context was used to build categories and themes retrieved from the original sources. All the data from several sources such as classroom observations, interviews, and group meetings were dated. Auditing therefore allows anybody to trace and view the original data sources, instruments, field notes, tapes, journals, or other artifacts. It is a way to raise authenticity of the research in an effort to provide a means for ensuring logical data synthesis to reach conclusions which can be confirmed (Mertens, 2005).

Ethical Issues

Ethical issues are extremely important and should be treated with great respect when doing research that involves human participants in order to avoid doing any harm to their lives (Sieber, 1998; Cohen *et al*., 2000;; McNiff and Whitehead, 2006). Ethical considerations play an important part in how a teacher improves upon their teaching practices. At the outset of a study, the researcher has to inform all participants of the purpose of the study. The importance of the study and its benefits to the participants should be clarified (Creswell, 2002). Any participation by individuals should be entirely on a voluntary basis and they should be allowed to refuse to participate in any aspects as the study progresses and withdraw from it at any time they wish. In the process of data collection, the "privacy, confidentiality" of the data that pertains to in-depth information or personal documents as well as how to control the access to the information by outsiders needs to be considered (Sieber, 1998). The researcher must negotiate and get permission to do the research before beginning the study. A permission letter was sent to administrators, schools, and participants explaining the purposed of the study and to gain permission to enter to the school throughout the time of the study. The researcher contacted the teachers who volunteered to participate in person and negotiated with the teachers and she brief ideas regarding the research, the teachers' role, teachers' work and so on. When teachers understood the commitment requirements on their part and were still interested in volunteering a letter was sent to all affected personnel for permission to do the study and work in the schools with the teachers.

When publication of the research takes place the participants' names and schools' names will not be used but instead referred to by pseudonyms. All of the results will be kept completely confidential. To protect the anonymity of the participants, none of the forms contained in the study will provide any information that would permit anyone to link the results to any participants whether they are teachers, students or schools (Sieber, 1998; McNiff and Whitehead, 2006).

CHAPTER IV

FINDINGS

Introduction

Chapter four is comprised of three parts that discuss three sample cases, Ms.Pimpon, Ms.Kanopon, and Ms.Sunee. The first part describes general information regarding the context of the study, the teachers' backgrounds; a description of the students and the classroom settings in which the study took place. Part Two presents findings from the first phase of the study that attempts to answer the first research question: How do geology teachers' actual teaching practices compare to the integrated curriculum's suggested teaching practices? Part Two provides examples of teaching practices categorized into themes and finally Part Three discusses the themes that emerged from the second phase of the study that resulted directly as responses to the study's second question: How do Geology teachers change their teaching practices after participating in the collaborative action research group (CAR)?

Case One: Ms.Pimpon (Warin School)

Teacher's Background

During the 2008 academic year, Ms.Pimpon taught 16 periods per week. She separated the two sciences into equal halves giving each the same number of class times, teaching the topics in one strand up to the mid-term exams and then the other strand in the second part of the semester. Astronomy topics were usually taught in the beginning of the semester and the Geology topics in the second part and this was done to raise the students' interest in studying Earth Sciences and thus Geology. The students already enjoyed studying the topics in Astronomy and scored higher on the evaluations regarding its topics than they did on the topics in Geology. It is for this reason that Ms. Pimpon decided to teach Geology after Astronomy even though this went against the arrangement of the textbook recommended by IPST.

In Ms. Pimpon's particular school, 8 out of 16 classes take Astronomy and Geology in the first semester and the other 8 take them in the second semester. The classes are double periods of 100 minutes per week and continue for six to seven weeks which means about 12-14 periods in total for the teaching of Geological topics.

The Context of the Students

The first group of students used in the study, were 51 students, 18 boys and 33 girls in the first semester section. They were all part of a group studying in the engineering-architecture program that is part of the Science-orientated programs of this particular school. The students were grouped heterogeneously and their average achievement score in Science while in the lower secondary levels was 3.28 out of 4.

The second group of 30 students, 10 boys and 20 girls, was quite different in that they were grouped homogenously based upon their high achievement in Science in the lower secondary level, 3.68 out of 4. Many of them came to this class from a variety of different schools once they finished studying in the lower secondary level. Five students from this group were granted scholarships from IPST to further study Science in order to make it their career. Quite often, these students were able to participate in actual field experiences held by the IPST and attend science camps held by several universities. They were considered to be gifted with high learning achievement levels in all disciplines of study in their lower secondary grades. Because of this, the school put these individuals into one class with fewer students than a typical class size so they could receive extra guidance from teachers.

Classroom Settings

For the first group, in the first semester, the students sat in groups and because the number of students, 51, was quite large the room was crowded with small spaces between each student. This crowdedness did not happen in the second semester because the number of students, 30, was smaller. The groups were organized based upon the students' pre-test scores given at the start of the semester, into mixed groups of higher and lower scores. These groups did not change throughout the semester. Ms.Pimpon always taught in the same classroom which had six large tables at which the students sat in groups of six. The walls were decorated with illustrations, diagrams, and maps discussing topics related to Geology such as the Earth's structure, geologic time periods, and continental plates, etc. There was a television in the room, but it was never used for teaching. There was an overhead projector in the front of the classroom which Ms.Pimpon sometimes used, but most often she used her laptop which was connected to a LCD projector in which she displayed pictures, video clips, or text files. When she showed video clips the quality of sound was quite poor because of the low quality of the speakers in the classroom. The classroom also contained a small learning centre in which there was a collection of teaching and learning materials consisting of various kinds of rocks, gemstones, crystals, fossils and models. Ms.Pimpon also placed materials she had collected from her own field trip experiences in the learning centre and things she had purchased from her own personal budget. Items donated by the students and their parents were also placed in this area. The students were able to look around the room at any of the materials on the walls or in the learning centre at anytime because Ms.Pimpon wanted the classroom to be open to the students who were interested in either Astronomy or Geology whenever they had free time.

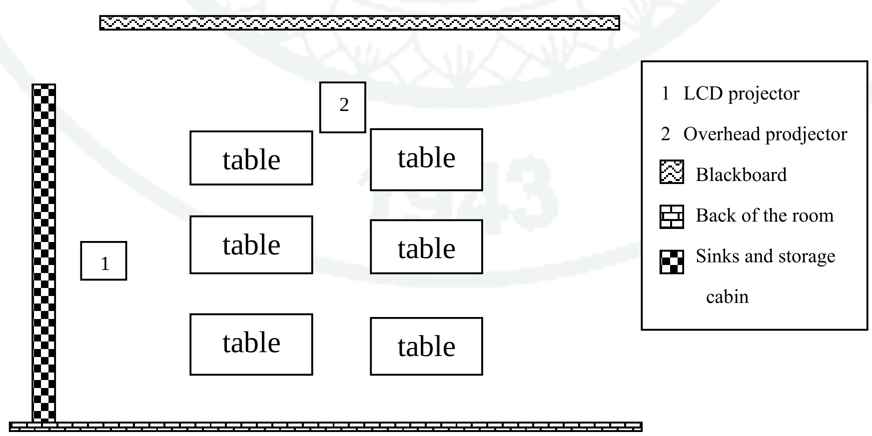


Figure 4.1 Layout of Ms.Pimpon 's Classroom

Research Question I: How do Geology teachers' actual teaching practices compare to the integrated curriculum's suggested teaching practices?

To answer the first research question, the researcher collected data in the first semester from: six observations, an interview, two lesson plans, and student worksheets in order to better understand Ms.Pimpon's teaching practices as compared to an integrated curriculum. Her teaching practices were interpreted using four main topics: teaching and learning processes, use of teaching and learning materials, assessment and evaluation procedures and the use of an integrated curriculum. After examining the data and evidence, several themes emerged.

1. The Teaching and Learning processes

Activities in lessons concerned with content on national examinations

At the start of most of her lessons, Ms.Pimpon often had the students do a multiple-choice format pretest on their own. The questions on these pre-tests were related to the content that she was going to introduce to the students on such geological topics as: definition of terms, characteristics of Geological phenomena, tectonics, geological time periods, or fossils. Some of the questions were taken from "recent examples of the Entrance Examination, or Ordinary National Education Test (ONET) that most Thai students are required to take. She stated that some of the questions came from practice worksheets that she designed herself (Second interview from August 8, 2008). On these worksheets, she included example questions from previous national examinations so they would have some exposure to those types of questions, especially in the area of living things in different geological time periods as this was a topic often found on national examinations. She stated that the purpose of the pretest was to give her an indication as to how much prior knowledge the students possessed in the area of Geology and so she could evaluate their understanding of any new concepts introduced at the end of the lesson.

> … Our school tries to give students the opportunity to get high scores on their examinations because students enter this school based

> upon the fact that this school puts great emphasis upon academics and is famous in the country for this emphasis. (Third interview from November 26, 2008)

It is evident from Ms.Pimpon's previous statement that she feels she has an obligation to uphold the school's long time academic excellence reputation and therefore she needs to support her students in ways that will help them perform to the best of their abilities on standardized tests and national examinations. She does this by using previous national examinations as a model for her questioning techniques and question format especially in her pretest questions.

Ms.Pimpon also believes that she has a responsibility to go beyond the standards and expose her students to topics not necessarily included in the standards, but that have been included on previous national exams and could be included in future exams. She presented a lesson that consisted of content about how to read a geographic map. She wanted the students to know how to read and interpret a graphic map so they could obtain more insight into geology. She had some negative reaction from the external team, outside the school educators, regarding her lesson because this topic was not included in the curriculum standards. She expressed dissatisfaction with having to design her lessons based upon the comments made by these external inspectors.

> … Each of my lesson plans had to attach with ONET exams … The requirement is at least in accordance with the curriculum standards. I developed a lesson about studying maps based upon a workshop I attended at Chulalongkon University. I thought the workshop's ideas were important so I put some emphasis on this topic. The external inspectors commented that I should look to see if this topic is included in the curriculum standards before I take up class time to discuss it. I did this and discovered that the topic was not in the curriculum standards, but it is in the textbook and it is included on the ONET exams. I concluded that the group should have a more open mind to some flexibility in what topics the teacher decides to introduce

> to the students especially when it only took a short amount of time. Is it not the teacher's responsibility to teach and outsiders to assess? This inconsistency really frustrated me as I want to make sure my students are completely prepared for their outside examinations. (Third interview from November 26, 2008)

From the comments made regarding Ms.Pimpon's lesson, it could be stated that a conflict exists between the perspective of curriculum planners and curriculum practitioners. It is the view of Educational inspectors that teachers should follow the standards precisely and not expose students to lessons on topics not included in the standards. Teachers on the other hand feel pressure to cover topics that may be on future examinations so their students can be successful and maintain their school's reputation. This is obviously the case with Ms.Pimpon's decision to cover topics not included in the national curriculum standards. Although numerous geology concepts required other basic knowledge in different areas, the students were rarely encouraged to integrate the understandings of related science knowledge which to enhance better comprehension on geology contents.

Providing hands-on experiments, but activities were more likely to be teacher-directed

From observations of Ms.Pimpon's lessons involving experiments it was obvious that she had the lead role in the lessons as the students followed her instructions and did exactly as she instructed them to do. She made sure that the students followed the correct procedures that would lead them to reach the expectations set out by her by the end of the lesson. She lead the discussion on recording data by using probing questions with the groups who finished up the task first and recorded their results directly herself in a table she had drawn on the board. When she attempted to discuss the results with her students and was met with only silence, she did not encourage them to answer she simply dispensed the information herself to the students and had them record the results from the table onto their own. Quite often, all this took place while some groups were still working on completing the tasks. As a result these lagging behind groups, simply stopped pursuing the task and “copied the results from the board without ever completing the task.” (Taken from Field notes August 8, 2008)

From the initial interview Ms.Pimpon explained that she did not provide the students with much opportunity to use scientific skills such as: formulating a hypothesis, discussing results and drawing conclusions, rather she dominated the discussion and dictated the conclusion in order to finish the lesson on time. It was here that she expressed her struggle between the implementation of good teaching practices and the constraints of having to cover all content and activities in one lesson allotment.

> … Actually, I would have preferred that they discuss the activity on their own, but instead I dominated the discussion. But if I didn’t lead the discussion then I could not finish the lesson on time and the students would end up only copying each other’s work. I did not discuss any of the scientific skills because they could read them on the experiment worksheets. But I am planning on having them do future activities more independently. I was in a rush to reach the conclusion. (Initial interview from September 19, 2008)

Many of Ms.Pimpon’s lessons skipped over the hands-on experiments component. These experiments are an important tool for students to be able to construct their own knowledge and as a result her students lack the ability to use the scientific process skills essential for obtaining scientific knowledge. She also did not give them the opportunity to use related scientific knowledge that could be used to explain Geological concepts.

Using worksheets as the primary activity in the lesson

Ms. Pimon’s major teaching tool was having students work from worksheets she developed from the materials she received from attending workshops. The students were given the worksheets in the beginning of the class to complete individually. Most often she required the students to complete the tasks outlined on the worksheets by the end of the lesson and then hand them in to her. She would then return them to the students at a later time to be filed for later evaluation.

The worksheets were divided into three types based upon their required task. First were worksheets that required the students to experiment and they contained some brief experimental instructions with space for recording results, conclusions, and questions. Most of experiments followed those outlined in the IPST textbook which provided more details regarding experimental instructions, necessary equipment and some photos. The second type of worksheet covered tasks that required the students to search for information, terminology or details of what the students were studying. Students had to search in the IPST textbook's diagrams and illustrations and then complete a fill-in-the-blanks worksheet. These worksheets also had a component in which the students had to color some diagrams such as the interior structure of the Earth "to increase their interest in studying Geology, otherwise they are not going to concentrate." (Initial interview from September 19, 2008) The third type of worksheet was a crossword puzzle that had the students find Geological terminology in English from the Thai explanations. These crossword puzzles came as a result of Ms.Pimpon's attendance at workshops and science camps and they focused on simple geological definitions or content such as "what is the name given to the super-continent in which all the continents were at one time joined together" or "where is the deepest layer of the Earth located that consists of iron and nickel". (Students' worksheet, crossword puzzle)

All the worksheets predominately focused upon geological content and used the following methods of recording: short-answer questions, data tables, illustrations, and games to examine student understandings of the concepts. The worksheets rarely included an effort to interconnect other scientific knowledge that is the basis for the explanations of Geological content. In fact, in order for the students to understand the explanations of the mechanisms of tectonic movement, earthquakes, or the Earth's structure, they need to have an understanding of convection currents, seismic waves, and/or chemical components.

The use of different activities for different groups of students with respect to their learning abilities

Class activities were sometimes differentiated upon students' learning abilities, especially between students in the science-oriented and non-science-oriented programs. The following example shows how she used learning ability as a tool for choosing who participated actively in an activity. In the lesson on volcanic rocks, the students performed hands-on experiments concerning the physical characteristics of volcanic rocks such as color and texture. Another part of the experiment allowed them to observe the reaction of hydrochloric acid on volcanic rocks and limestone, but all the students were not given the opportunity to observe by themselves because Ms.Pimpon requested only five students who were really interested, observe this part. The rest of the students had no idea what would happen in this activity unless Ms.Pimpon wrote the results on the board. She described her intention to not allow all students to do this activity because "they would mess things up." (Initial interview from September 19, 2008). She restricted the use of the acid by certain groups because she was afraid of the mess if they did it incorrectly.

The following gives a situation in which Ms.Pimpon differentiated based upon whether the students were science or non-science students. For instance, some scientific skills such as formulating an experimental hypothesis were included in activities used when teaching students with high competency, typically science-oriented students, while activities for non-science oriented students, eliminated this part. For example, in an activity about surface waves the science-orientated students were allowed to use a water box to demonstrate the propagation of surface waves. This component was not included in the lesson for non-science-oriented students. They were just required to passively transfer the procedures of the activity with a picture on the board and then answer a few questions about the activities results. In the follow-up interview, Ms. Pimpon stated:

> … In chapter 1 and 2, I gave all of them (*objectives and hypothesis*) to the students, but … I had another set of worksheets which allowed them to write it (*hypothesis*) and design it by themselves, if they

> were the bright students. I did not use it with every group of students. For the less bright students I told them step by step what to do and sometimes they didn't even do anything. Another set of worksheets was given to the students to do on their own and I did not tell them much. Do it yourself. For the bright students in the second semester, I let them design an experiment and let them generate their own wave. (Initial interview from September 19, 2008)

2. The Use of Teaching and Learning Materials

Although Ms.Pimpon did use the IPST recommended textbooks, it was obvious through the classroom observations, interviews, and teacher documents that she also used a variety of teaching and learning materials in her classes that pertained to Geological content. Her teaching and learning materials could be classified in the following ways:

Using real specimens in order to promote students' first hand experience of Geology

Ms.Pimpon used real specimens, such as different types of volcanic rocks, fossils found in sedimentary rocks and crystals for experiments or demonstrations. All of these specimens were from different sources (e.g. field trips, workshops). She also devoted a part of her room to display additional learning resources for anyone who was interested in studying further about geology. These included examples of student work like projects or models. The main purpose of using real specimens was to "provide first-hand experiences for them (*the student*)" (Initial interview from September 19, 2008). For example, the use of volcanic rocks (e.g. basalt, phydite, andesite, tuff, and pumice), or various gemstones to investigate the physical characteristics of volcanic rocks, such as texture and color.

Because Geological phenomena primarily occur in a natural setting, the classroom is not the most natural location in which to learn about this type of phenomena. It is important therefore that students participate in some hands-on related experiences and thus field trips are very worthwhile activities. But it is very difficult to arrange such activities because of school policy, budget restraints and the complexities of related student safety issues. Ms.Pimpon attempted to bring the idea of field trips into her classroom by providing the students with real life examples of specimens that they could manipulate and perhaps this would help to increase her students' interest in Geology in the future.

Model usage to simulate the physical characteristics of Geological phenomena and the mechanisms that drive these phenomena

Because Geological phenomena do not occur easily in a school lab setting, Ms. Pimpon employed many ready-to-use models for her students to use in order for them to investigate these phenomena. For example, during one classroom observation session, this researcher observed Ms.Pimpon's use of a moveable wooden frame with three different colored sheets of plastercine attached that when moved simulated the characteristics of a planar fault line and its consequences. This model showed that when the two sides of a fractured rock moved, the layers of plastercine also changed shape. These represented the effects this type of movement of the Earth's layers had on the Earth's surface and the subsequent damage that could result from fault movement. Unfortunately, this model could not show the mechanism that caused this type of fault movement to occur like convection currents or frictional forces within the Earth itself. Models had some limitations.

Ms.Pimpon used another type of modeling activity to simulate the creation of a fossil. The students were assigned to create an artificial example of some kind of plant or animal. To imitate the process of creating the resulting fossil, a layer of plastercine was used to make a mold of the living thing which in this activity was a bivalve shell. The students pressed the shell into the plastercine and then pressed another layer of plastercine on top of the shell. The plastercine was then removed and plaster of Paris was placed into the mold and then let dry. By doing this type of activity, students were able to understand the process by which fossils are formed, but there was no discussion as to their importance in providing information to paleontologists about how life has evolved.

3. Assessment and Evaluation

Worksheets as the major post class assessment tool

From the researcher's classroom observations it can be concluded that Ms.Pimpon's main method of assessing her students learning was from the worksheets they completed in class each time. Students had to hand in the finished worksheets right after class and as a result she rarely discussed the worksheets with her students as a whole group during class time. She simply evaluated their understanding from their responses to the variety of activities laid out on the worksheets. She did include on some worksheets the criterion for which she would base her evaluations. She used a five scale rubric starting with a score of zero for not handing in the worksheet to 4 points for answering the questions correctly or following the directions explicitly, such as coloring a diagram correctly and neatly. But because the worksheets generally dealt with Geological topics that would be more likely emphasized on national examinations, the students' understanding of Geology concepts was narrowed by this restriction. Not often did Ms.Pimpon include other areas of science that were related to Geological phenomena.

Traditional paper-and-pencil tests

Paper-and-pencil tests were utilized to assess the students' understanding of Geological phenomenon prior to starting the unit and at the end of the unit. Their pre-test scores were recorded and used as a "baseline for placing students in groups according to their multi-abilities" (Initial interview from September 19, 2008). At the end of the unit the students were tested on the same content and then these scores were compared with their pre-test scores and this difference was used as an indicator of the students' levels of learning.

4. Using an Integrated Curriculum

Focus more likely on interdisciplinary integration and less on intradisciplanary on content knowledge

Ms.Pimpon recognized that Geological phenomena is interconnected to other areas of science and she did use crossword puzzles to try and integrate English into her lessons as well as being a way of making the class enjoyable while at the same time giving them an opportunity to learn the correct pronunciations of the terms in English. Ms.Pimpon exhibited her recognition on integration of Geology contents with:

> … (*The purpose of puzzle is)* to be relaxed. There was no need to explain each vocabulary word as they could use the textbook. Sometimes, I just told them to open up to a particular page and they would see the word and how it related to the English language. I told them that if they did this activity, their English teacher would give them extra marks. She (the *English teacher*) taught them how to pronounce some of the (*geology*) vocabulary correctly. She even told me (*Ms.Pimpon*) to let the students match the Thai with its English vocabulary, but I (*Ms.Pimpon*) have not tried that yet … We (Ms. Pimpon and the English teacher) were trying to encourage them to get comfortable with both the Thai and English terms. She (the *English teacher*) understood what the science teacher (*Ms.Pimpon*) wanted the students to learn and it was necessary for this integration between her (Ms. Pimpon and the English teacher (Second interview from August 8, 2008)

Ms.Pimpon also tried at times to integrate Geological content into other disciplines. For example, the students made a handicraft lamp in different shapes of crystals when they had learned about crystal formation in minerals. This showed the relationship between an occupation and technology. This example shows that Ms.Pimpon is concerned about integrating Geology with other disciplines. Also, the school promotes the idea that teachers in different departments talk and share their experiences in teaching in order to make them more effective teachers in every subject area.

In terms of integration within science, particularly Geology and other areas of science, she mentioned that she hardly ever interconnected Geology with other science subjects. She integrated some Geological content with biological content, including teaching fossils with the use of paleontology, or the monitoring of the age of rocks with chemistry concepts, such as the topic of half-life radioactivity.

> …For example, in paleontology…This (*fossil*) is evidence of the evolution of living things. Trilobites had been on Earth for millions of years. They constantly evolved, but they do not exist in present time because they could not adapt themselves to all changes and this is not only a concept in paleontology, but in biology as well.” (Second interview from August 8, 2008)

Inadequate background knowledge in other science subjects is one reason for the lack of intradisciplinary integration

Ms. Pimpon asserted that she rarely integrated other science subjects within the Geology concepts, especially physics because she does not have a strong background in physics.

> …We spend a very little time discussing physics and how its content relates to Geology, but if it is a necessary concept, like heat transfer, then it needs to be mentioned more frequently in order for the students to understand the Geology (Initial CAR group meeting from November 27, 2008)

> …I hardly interconnect Geological concepts with other science subjects, especially physics because I think I do not have an adequate understanding of physics. Thus, I hardly use physics in teaching Geology (Second Interview from August 8, 2008)

In summary, in the first semester, Ms.Pimpon primarily relied on worksheet type activities that typically focused on examples from the national examinations. Students participated in some hands-on activities but generally the activities can be described as mind-off, passive, with the teacher most often leading any discussions. As well, some activities were chosen simply to suit the students' abilities which meant that better students participated more often in more complicated activities while lower students in more passive ones. In terms of the use of teaching and learning materials, Ms.Pimpon frequently used models to simulate authentic Geological phenomena, but she did not integrate actual Geological mechanisms that require other scientific knowledge to understand these phenomena. She utilized real specimens as often as possible to provide first-hand experiences for her students. In terms of assessment and evaluation, Ms.Pimpon primarily used student worksheets to evaluate students' learning achievements. She also used the traditional paper-and-pencil test as a method of pre-test and post-test. In terms of using an integrated curriculum, Ms. Pimpon stated that her teaching practices were mainly interdisciplinary rather than intradisciplinary based upon her knowledge or lack of knowledge of a particular subject.

Research Question II: How do Geology teachers change their teaching practices after participating in the collaborative action research group (CAR)?

To answer this question, the researcher conducted six classroom observations, six post-class interviews, gathered evidence from the CAR group meetings, three teachers' lesson plans, and other related artifacts such as worksheets or reading sheets.

1. The Teaching and Learning Processes

Eliciting students' prior knowledge by using similar methods, but not really for diagnosing student understanding

The CAR group members discussed the importance of eliciting students' prior knowledge as a part of the constructivist approach by using an example of a lesson plan that the researcher brought into the first CAR group meeting. The members discussed the purpose of examining students' prior knowledge in order to diagnose the students' understandings or conceptions of a particular content. The research used a type of question that fit into the label of a "diagnostic test" which typically consists of open-ended questions that are not judged as either right or wrong. The students' answers on these tests were examined and then placed into several categories based on a specifically designed rubric. The CAR group members also suggested that the students' basic knowledge of physics, chemistry and biology topics that relate directly or indirectly be evaluated in order to have a baseline upon which to monitor any changes in their knowledge levels at the end. To do this, Ms. Pimpon used a similar method employed in the first semester, multiple choice tests using questions taken from previous ONET or entrance examinations and other resources. The students were given these tests at the beginning of each class with a short amount of time in which to complete them. Ms.Pimpon rarely discussed her students' prior knowledge, but she did point out to them that the purpose of the pretests was to generate individual student awareness of their understanding of each lesson. But she herself never knew into which category their understanding should be placed. She found it difficult to create new diagnostic tests because of her heavy workload and she had "no time to work from the beginning … and already had lots of pre-tests photocopied on the shelves." (Third interview from November 26, 2009).

In spite of the that she only used one method of pre-testing discussed in a CAR group meeting, time constraints and workload were the main reasons why she employed only this method and it was not easy for her to change.

Giving students more opportunities for participation in hands-on classroom activities, but less opportunity for the students to be active

As was stated previously, in the first semester, Ms.Pimpon played a central role in almost every part of the lesson. Ms.Pimpon's actions dominated all processes including: writing data, giving explanations, drawing images, or drawing conclusions without much student input. By contrast, in the second semester, after a discussion with the CAR regarding providing students with more student-centered activities, it was seen that Ms. Pimpon designed her lesson plans and arranged activities in many classes to provide these types of opportunities for more student engagement. Students were allowed to be more involved in talking, discussing, writing, or drawing during the lesson. When doing hands-on experiments, they were asked to participate more in the scientific processes: recording data from observations, or drawing pictures on the board in front of the class. They were also sometimes asked to express their understanding after studying or reading sheets in front of the class.

However, there was also some dissatisfaction regarding student participation in the class as well, particularly the fact that there was less collaboration in groups working on hands-on experiments. Consequently, most of the students were unable to finish the activity on time. Ms.Pimpon could not wait for all groups to finish and record their results on the board and then discuss the results as a whole class. She decided to call a volunteer from the groups who finished first to record their results, despite the fact that other students were still working on the task and would therefore be excluded from any class discussion. Eventually, the unfinished groups simply quit and copied the results on the board onto their worksheets. Ms.Pimpon commented that:

> …Some students were not cooperative with others, but the boys were… Some of them did not touch anything until other students started to. There were two groups of them who finished first …. They did not read if I did not tell them to. What was I supposed to do? (Third post-class interview from January 13, 2009)

The students were not familiar with the new teaching practices in which the teacher gave them more opportunities to be involved in student-directed learning, rather than teacher-dominated teaching like in the first semester.

Enhancing student participation by using group reading and presentation

To increase her students' participation in the class, Ms. Pimpon initially designed reading activities that were different in sub-topics for different groups of students. In the structure of the Earth topic, for instance, there were five sub-topics about the evolution of the Earth which described the procedures of the formation of hot molten substances that solidified into each layer of the Earth, the physical properties of the crust which are classified into SiAl and SiMa rock, characteristics of mantle and its position, the two distinctive layers, the outer core and inner core, terminology of lithosphere and asthenosphere. Each group was given a reading sheet of each sub-topic and was asked to present their understandings to the class. Regarding this activity, the CAR group members gave suggestions that each student should study individually and then with their group the five sub-topics altogether. These topics are dependent upon other related content from other areas and thus it would be difficult to “study these topics fragmented from other topics in order to understand the whole picture of the structure of the Earth” (Second CAR group meeting from December 13, 2008). Another suggestion for improving the students’ learning was simply to have them read and present what they have learned. Students should be given the main ideas by using “post-reading exercises that monitor what they have learned from the reading sheets” (Second CAR group meeting from December 13, 2008). These exercises could also be used to show the integration of Geology content. The questions in these types of exercises should guide the students understanding in the interconnection between other disciplines in science and the content found in Geology as well as encourage the students to use their more higher thinking skills by making the exercise question more difficult rather than asking them just to recall facts. The last suggestion was regarding the use of example questions from national examinations on the worksheet as Ms.Pimpon did in the first semester. After discussion, the CAR group members agreed the use of these questions should be reduced because the focus of teaching should not be on passing the national examinations but rather on promoting the learning of the students. In other words, don’t teach to the test. Ms.Pimpon learned a lot from the comments of the CAR group and revised the sequences of her reading sheets to combine all topics together and created post-reading exercises to monitor her students’ understanding after the readings.

In the classroom, the students enthusiastically participated in this activity because Ms.Pimpon gave extra marks to whoever presented in class. However, sometimes they simply read the contents of the reading sheets to the class instead and thus the presentations were not their own words, nor were their conclusions. They still did not seem to show an understanding of the content and furthermore, many students seemed to not pay attention and instead of listening carefully to their peers, they were chatting in pairs or small groups.

More hands-on activities to enhance student learning

Ms.Pimpon did improve her teaching practices by having more activities in her lessons. For example, in the lesson about volcanic rocks, Ms.Pimpon allowed all the groups to have a hands-on experience by observing the physical characteristics of various volcanic rocks and observe the chemical reaction that occurs when hydrochloric acid is placed on these types of rocks. This type of activity differed from what Ms.Pimpon did in the first semester because at that time she did not allow all the students to use the materials because she simply provided them with the results of the activity. As a matter of fact, even though a specialist from IPST told her that this type of activity was not necessary for the students to do, she felt it was valid because the relationship between rocks and their reaction to hydrochloric acid would be very important when she introduced concepts from the next chapter.

> …Volcanic rocks, actually Ajarn Sinn (*specialist from IPST*), stated that it is not necessary to do the acid and rock activity. He asked why I continue to have the students participate in it. I told him that it is an important concept in the third lab in the third chapter when we introduce the concept of fossils in sedimentary rocks. It's okay to have already done this experiment. I don't want to do it again because it's complicated except for the students who are interested (Fourth post-class interview from January 20, 2009)

Some activities were given to the students in the science-oriented program to ensure their understanding. For example, the activity about creating surface waves within a water filled plastic box was included in the lesson about earthquakes and fault lines. Using a transparent plastic box filled about three quarters with water and a large rubber band wrapped around the edge of the box, the students pulled out the rubber band and let it tap on the box, then they observed what happened in the box. Then, the students dropped a small piece of colored ribbon on the surface of water when tapping the box with the rubber band. They observed the displacement of the ribbon on the ripples of water created along the water surface. This activity was used to integrate the idea that the characteristics of waves on water can be used to explain the characteristics of seismic waves as well.

2. The Use of Teaching and Learning Materials

Using real specimens in order to draw student attention, to increase student interest, and to integrate with related concepts

In the second semester, Ms.Pimpon used real life specimens which were similar to the ones she used in the first semester. The use of real specimens offered first-hand experiences for the students while at the same time increasing the students' interest in Geology. Ms.Pimpon tried to make the activities involving real life specimens realistic by putting more emphasis on the explanation of volcanic rocks and their appearance in everyday life as gemstones rather than just on how they were created. She brought in examples of gem stones already made into jewelry like black sapphires and other polished stones. She also showed slides of different gem stones such as opals, rubies, and garnets. The students seemed very interested in these pictures and thus she extended the time spent on this activity. She stated:

> …Students are usually more interested in the uses (*of rocks*) rather than in talking about their characteristics. (*For example*) I'd like them to know about Spinel (a *mineral*) in basalt rocks. It (*the IPST textbook*) has only two lines about gemstones, but the students are very interested in this topic so I spend some time on it in class. … Perhaps, this would make them much more interested in studying (*geology*). I have to tell them what they could use them for in the first place ... as they have no idea. But, if they see these gemstones, they know where to go, and when they learn chemistry and study about radioactivity they can

> relate it back to their study of gemstones as they change their structure, when they have been irradiated they change color, from colorless to colorful. They will learn this with chemistry teachers in the future (Fourth post-class interview from January 20, 2009)

Employing worksheets, reading sheets, and post-reading exercises

Unlike in the first semester, Ms.Pimpon did not use the same worksheets in every class, but she developed reading sheets for the students to study further details of each lesson and added questions regarding post-reading exercises for the students to fill in. Reading sheets were given to the students to study and to answer questions within a group during the class and these were handed back to the teacher at the end of the class so she could evaluate their understanding. One set of reading sheets comprised several topics. Each topic provided details in text or figures with a varied number of details, some of them were relatively short paragraphs, and some of them occupied a whole page. Content on the reading sheets were from various resources, such as a dictionary of Geology, related Geology textbooks, or booklets. Typically, the content on the reading sheets were composed of content as it related to topics such as the Earths' structure, definition of terms like lithosphere and asthenosphere, and the consequences of Geology. Some of reading sheets were developed in order to integrate related concepts of physics with Geological content.

The post-reading exercises were used to monitor the students' understanding after studying the reading materials. Most of the questions were open-ended and some of them were fill-in-the-blank. Most of questions required factual knowledge gathered from the reading sheets or the textbooks.

Using models with simple characteristics to capture student attention, but yet neglect to clarify on how the central concepts these models are to explain relate to Geological content

As mentioned earlier regarding her use of models in the first semester, Ms.Pimpon tended to only use models to represent physical properties not the mechanisms behind how the phenomena work or occur in nature. In the second semester, she changed her approach slightly to ensure that the knowledge behind the model was clearly explained. For example, she showed examples of artificial fossils like Ammonites (helically-spiraled-shell marine animals), Trilobites (three-lobed body arthropods), and Fusulinids (shelled amoeba-like marine protists) so the students could see the physical appearances of these ancient creatures and speculate on their habitats. Each group of students had to search for information regarding these ancient creatures from their textbooks, diagrams, given worksheets (of Ammonite) such as the age of these living things, what Geologic time periods they lived in, their living environment, and where to find their fossils remains. She also raised these same points in follow-up discussions and how what they found out related to the local geography. She adapted the idea of simulating the production of a fossil from the mesh like fabric of a luffa sponge that was suggested by Ms.Sunee in the third CAR group meeting. This model was used to represent the idea that a fossil is a replacement process that occurs when tissue or pieces of an exoskeleton are replaced by another mineral. Another example Ms.Pimpon attempted to use was when fruit and seeds are removed the network of xylem cells remain and when the plant is dipped in a blue solution of dissolved copper sulfate it fills the cavities left among the fibers. Unfortunately, the sample was partially covered with solid crystals due to an insufficient amount of the concentration or not enough time was given for the crystallization effect to occur properly. Hence Ms.Pimpon did not use this sample in the class.

Even though Ms.Pimpon used the fossil model to simulate the production process involved in creating a fossil she did not discuss the key idea that by studying fossils it gives evidence regarding the evolution of the Earth and all living things from ancient times to the present. Fossils from different Geological time periods are evidence to how these living things evolved in structure and habit and how these ancient living things have evolved into the complicated organisms we see today.

3. Assessment and Evaluation

In general, the assessment and evaluation of the students' learning in the second phase of the study were quite similar to the first because Ms.Pimpon used almost the same activities as in the first semester. Basically, traditional pencil-and paper pretest and post-test were used to monitor her students' improvement before and after studying the Geological concepts.

Worksheets as the primary assessment tool of the lessons with post-reading exercises

Ms. Pimpon commonly used worksheets to assess her students that focused on the cognitive domain. These worksheets were used during the unit as a method of monitoring her students understanding of the concepts she was presenting in class. In the second semester Ms.Pimpon added an additional assessment called post reading exercises. These focused on the cognitive domain in which the students read a passage and then tested their knowledge. Additionally, she did ask questions during class to which the students would answer orally to monitor their progress and she sometimes walked among the groups as they were working and asked them questions about what they thought they were learning, but most often she questioned the class as a whole after she had gone over the concept with the group as whole. For example, she explained a graph regarding the idea of half-life in dating rocks and then she would ask questions.

Ms. Pimpon: Would you like me to explain more of about the graph of half-life?

Students: Yes.

Ms. Pimpon: We have a question about this graph and how to use it. Is says that if a living thing has decayed 25%, then how many years has it taken? Question number 3, if there is radioactive element that has a half-life of 5,000 years, how long would it take to decay to 25%

Students: 10,000 years

Ms. Pimpon: 10,000 years, okay. How much of the element was present in the first place? When it decays one half of its original proportions, that period of time is called half life. (*writing on graph of exponential decay*). The original proportion is here (*dotting on 100 percent on proportion on Y-axis*) and then it decays one half, do you understand? Then it decays one half of this half, so how much of it is left?

Students: One fourth

Ms. Pimpon: One fourth is one half squared, isn't it?

Students: Yes.

Ms. Pimpon: How much would be left when another half-life elapses? It's one half to the power of three. Then you can write the equation that the decay proportion equals one half to the power of n. N is the number of half-lives elapsed … So, one half to the power of three is one eighth. How much is it if you calculate it as a percentage?

Students: 12.5

Ms. Pimpon: 12.5, but the question said…how many times do you think it decays to have 25 percent left?

Students: Twice

Ms. Pimpon: It's twice, isn't it? … If we know the number of half-lives that have elapsed, we know time (*half-life period*), what we can we do with this? We can verify the age of decaying (*fossil*) … So, what is your answer to this question?

Students: One million years

Ms. Pimpon: One million years? Or is it 10,000 years?

Students: Yes.

Ms. Pimpon: Once is 5000 years, so twice is…

Students: 10,000 years

(Fifth classroom observation from February 5, 2009)

In terms of assessment and evaluation of the psychomotor domain, Ms.Pimpon observed the students' performance showing their skills and abilities while performing a particular task. In the fossil production using plaster of Paris, she assessed the students' skills while they prepared the mold. She observed how they mixed the plaster, inserted it and finally the end product. Evaluation of the affective domain was done through whole class discussions and the short answer questions on their daily worksheets regarding how to apply Geological concepts to everyday life.

4. Using of an Integrated Curriculum

Integrating related other science content knowledge with geology content knowledge through organizing activities in order to increasing the recognition of integration for the students

Ms.Pimpon created several series of reading sheets and post-reading exercises according to the suggestions that came from the CAR group. Especially in her post-reading questions by making them relatively important for monitoring the students' understanding or thinking skills. More importantly, these exercises could be the place for integration in other science subjects and Geological contents. Questions should promote students' thinking skills from reading, not just by merely recalling facts, or definitions. They could involve the understanding of other related science contents which would help the students obtain a better understanding of Geological content. However, Ms. Pimpon should still revise some of her reading sheets and post-reading exercises according to suggestions from the CAR group or the researcher herself.

Some of the questions in post-reading exercises were originally developed by the teacher and some of them were suggested by the researcher. The researcher suggested including questions that would enhance the students' ability to critically integrate the content on the sheets. For example in the earthquake questions the students could be required to classify the differences between P-waves and S-waves in terms of their formation, velocity, and examine the similarities and differences between these waves as they are formed on the Earth's crust and how they affect tsunami waves. Ms.Pimpon developed reading sheets about earthquakes that included the properties of the different kinds of seismic waves, but she did not include any questions on this topic in her post-reading sheets. Perhaps this was because she was not familiar with the physics principles involved in this concept.

Examples of questions on other topics are shown below:

-Evolution of the Earth began after the big bang about.............years

-Iron solidified to become a part of the Earth's structure and was accumulated in the layer called …………

-Where are the thinnest areas of the crust located?

-What elements are composted within the thinnest areas of crust?

-What does the upper mantle look like?

-Which has a solid form the outer or inner core?

-Lithosphere is located below the Earth surface about……………….

(Post-reading exercise, Earth's structure)

Moreover, Ms.Pimpon organized hands-on activities to interrelate the concepts of physics and geology. For example, the activity about creating surface waves within a water filled plastic box was included in the lesson about earthquakes and fault lines. Using a transparent plastic box filled about three quarters with water and a large rubber band wrapped around the edge of the box, the students pulled out the rubber band and let it tap on the box, then they observed what happened in the box. Then, the students dropped a small piece of colored ribbon on the surface of water when tapping the box with the rubber band. They observed the displacement of the ribbon on the ripples of water created along the water surface. This activity was used to integrate the idea that the characteristics of waves on water can be used to explain the characteristics of seismic waves as well.

Showing a positive disposition to the integration of Geological content knowledge through various types of activities, but superficially touching upon significant ideas from related areas of science

Ms.Pimpon gradually developed methods of integrating other science disciplines into her Geology lessons. She primarily relied on reading sheets and leading questions to raise students' concerns regarding integration. Moreover, she used additional activities to generate integration within other science disciplines. For example, the discussion about fossils from ancient times which might enhance the students' thinking regarding related science subjects, such as the evolution of living things.

Ms. Pimpon: In which geologic time period did the dinosaur appear?

Students: Jurassic (writing information on a board)

Ms. Pimpon: What about Trilobites?

Students: The first period

Ms. Pimpon: What is this period called? Cambrian. How many years ago was this period?

Students: 500 million years (writing information on a board)

Ms. Pimpon: What about the trilobites' habitat? Marine or terrestrial animal?

Students: Marine.

Ms. Pimpon: Yes (writing information on a board). This (Trilobite) was found in Phuket (writing information on a board). Can you order these organisms from the most ancient to the most recent?

Students: The first place is the Trilobite.

Ms. Pimpon: Yes, and what about the Ammonite?

Students: Second

Ms. Pimpon: Which (geologic time) period did the Fusulinid exist?

Students: Permian

Ms. Pimpon: From Permian until? Quick! There is the description on the worksheet, isn't there? No, from the Caboniferous until the Permian. (writing on board) What about its age? 300-280 million years. And what about the age of dinosaur? 200-65 million years (writing on a board). So which is the most ancient thing? Trilobites and what's next? First is the trilobites and then…...

Students: Ammonite, Fusulinid

Ms. Pimpon: The last is the Dinosaur…These living things do not exist in present time, but we can verify its absolute age using an index fossil. All of these fossils were found in Thailand. It tells us the past environment of Thailand. For example, the Fusulinid that I gave you was found in the central plain. That means the central plain in the ancient time would be a……?

Students: Sea.

Ms. Pimpon: Sea and shallow water as well for it was in a warm ocean current. It was in the ancient sea.

Students: How do we know whether it lived in the sea or not?

Ms. Pimpon: Paleontologists have already conducted research and found these living things only in our region that had warm ocean currents. It is impossible for it to be in the sea around America. So what are the benefits of studying fossils?

Students: It tells about geography.

Ms. Pimpon: Geography of area in which we found them (fossils), right.

Students: Where were dinosaurs found?

Ms. Pimpon: Where?

Students: Kalasin province

Ms. Pimpon: Yes, great job. Fossils of a dinosaur were found in sandstone….

(Fifth classroom observation from February 5, 2009)

This excerpt of classroom discourse addressed the simple idea of the characteristics of fossils, their age, and their benefits for giving evidence related to ancient geographical environments. However, Ms.Pimpon sometimes did not always arrange her activities in the most effective way to integrate the key ideas that can be related to other science disciplines. She reflected that she integrated the idea of evolution in the lesson by discussing various fossils from different geological periods she did not mention how the evolution actually occurred. She should have discussed how evolution is related to how living things adapt to changes in their environments which means they change from simple to more complicated organisms or how the number of ancient creatures moved from being mostly marine to now being mostly terrestrial.

Low confidence to teach concepts which are out of her area of expertise and asking for help from colleagues

When planning the lesson Ms.Pimpon reflected upon her feelings of being uncomfortable about integrating those areas of science that she felt she lacked the correct knowledge to discuss. In the fourth CAR group meeting, she stated that she did not possess adequate knowledge about the chemistry concept in the Earth's structure. It made her feel awkward when students asked her questions that went beyond her background knowledge. For example, when teaching the Earth's structure, the students asked about the differences between silicon and silica because the teacher used these two words to explain the component of the Earth's crust. She could not explain clearly. She had to ask the chemistry teacher later. She also mentioned her inadequate knowledge of physics to correctly understand the simulation of the movement of surface waves in a plastic box of water.

> …I really wanted to invite the physics teachers to help out. Students would get more understanding. But, I could not find anybody. We lack teachers so everyone was busy….I don't have a strong background in some content…..I also lack confidence when my background is not strong in an area. Sometimes the bright students helped me out by explaining to their friends (Third post-class interview from January 13, 2009)

From Ms.Pimpon's perspective she believed that her ability to teach Geological concepts would be greatly improved if there was better collaboration with other science teachers especially with physics teachers as so many physics concepts are part of Geology. She rarely integrated physics concepts into her lessons in the first semester because she did not have a strong background in it and she lacked confidence. Thus, in the second semester she planned to ask her colleagues for assistance in the topic of wave. She approached the Physics teacher to ask her to teach the concepts related to seismic waves and be a guest speaker. She had learned from her experiences in the first semester that when she, Ms.Pimpon, taught this topic the students did not understand fully and she could not explain it more clearly. She did not expect the Physics teacher to be available to come to speak to her class, but she was for a short part of the class.

> …I went to see her this morning and I asked her if she had time available *(this afternoon)*. It was definitely unofficial *(invitation)*. She said that she did not have any classes … Please come if you're free … I said if you could talk about waves. I think the students are having difficulty and I think five minutes would be enough. These students are in the special class. They need to have some concepts given more time.... If they misunderstand some concepts it may affect their understanding of other content (Fourth post-class interview from January 20, 2009)

When acting and observing the class as she planned, Ms.Pimpon reflected upon her integration of physics concepts into her Geology lessons as:

> …I did integrate, but I am not quite satisfied. I integrated some physics content this time … It was about wave and energy transfer, I think. The upper crust moves because it is hot underneath. I think it is integration … I just asked students and we discussed (Third post-class interview from January 13, 2009)

It can be seen that Ms.Pimpon made an effort to integrate Geological concepts with physics concepts even if she was not confident to teach them herself because of her limited background knowledge in physics. She decided to invite a guest speaker, the school's physics teacher. They did not have a chance to plan any activities together, but it seemed like a good idea to ask someone for help in this particular circumstance.

In conclusion, Ms.Pimpon obviously changed her teaching practices in various ways from the first to the second semester. In terms of the teaching and learning processes, she attempted to make her classes more student-directed fostering more student participation in discussions, presentations, and she added more hands-on activities in order to help increase her students' understanding of the concept she was trying to teach. In terms of her use of teaching and learning materials, she still primarily relied on students' worksheets. She did create some reading materials for students to study in class and used post-reading exercises to monitor her students' comprehension. Her teaching and learning materials were relatively similar to earlier samples. In the area of assessment and evaluation, she clearly focused on the cognitive domain by using in-class questions and fill-in-the blank worksheets and traditional tests. She did create additional post-reading exercises to assess the construction of the students' understanding from the suggestion of the CAR group members. Observation of students' performance during tasks was used as authentic assessments. Her use of an integrated curriculum changed immensely from the first to the second semester. She used more activities to interconnect other science disciplines with the Geological concepts and collaborative more often with colleagues in the second semester.

Case Two: Ms. Kanokpon (Isara School)

Teacher's Background

Ms.Kanokpon teaches 4 Geology classes per semester with a total of 8 periods per week and she teaches a fundamental science course to the non-science students in Grade 12 (Mathayom 6) for a total of 8 periods per week. A Geology course is provided for all students in tenth grade and it is usually arranged so that it is taught prior to Astronomy with both courses completed in one semester. However, four out of eight classes, usually the non-science students, study Geology in the first semester and the science streamed students study it in the second semester. All students study Geology in two back-to-back periods for 100 minutes per week, roughly 16 periods per semester.

The Context of the Students

In the first semester, the observed class consisted of 45 students, 13 boys and 32 girls of mixed abilities with an average learning achievement in science of 3.27 out of 4 in their lower secondary levels. In the second semester, the observed class consisted of 44 students, 11 boys and 33 girls who were all in the mathematics-computer program mixed heterogeneously with an average learning achievement in science of 3.27 out of 4 in their lower secondary levels.

Classroom Settings

Ms.Kanokpon's classroom was relatively large compared to the number of students. Students sat in six groups each at six large desks. The room had a number of teaching tools: one television to which the teacher could connect either a VCD or DVD player, an overhead transparent projector, projects made by students from previous years, and a variety of teaching and learning materials that were kept permanently in the room. Ms.Kanokpon also used her own laptop. Ms.Kanokpon displayed the student projects at the back of the room and these included models that related to Geologic topics such as volcanoes, tsunamis, fossils, etc. Diagram of her classroom shown in Figure 4.2

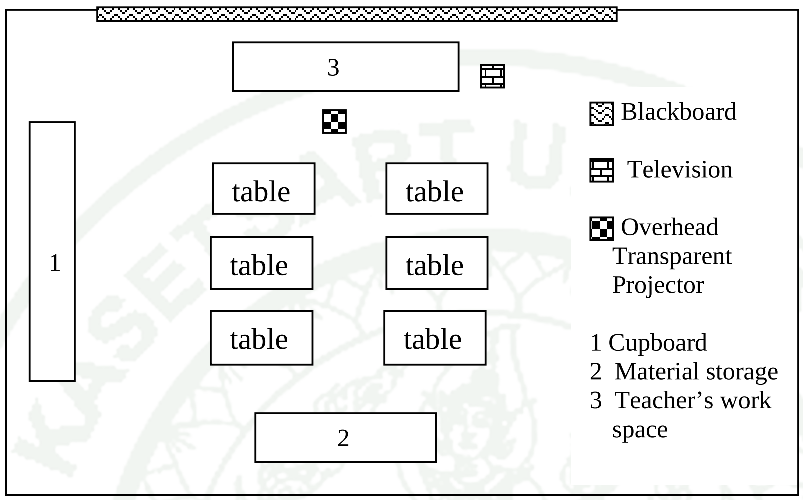


Figure 4.2 Layout of Ms.Kanokpon's Classroom

Research Question I: How do Geology teachers' actual teaching practices compare to the integrated curriculum's suggested teaching practices?

To answer the first research question, the researcher conducted three classroom observations of two back-to-back class periods in the first semester, two interviews, two lesson plans and various examples of student work. Teaching practices with regards to Geological concepts are categorized into several themes based upon the evidence gathered by the researcher from the above mentioned data collection techniques.

1. The Teaching and Learning Process

Teacher as the dispenser of knowledge with emphasis on the intellectual domain

From classroom the classroom observations, the researcher observed that Ms.Kanokpon mainly explained the Geological concepts by simply reading aloud to the class what she wanted them to take notes on. She described Geological terms, such as earthquakes or faults and provided definitions for them as well as providing a classification for each term such as volcanic or earthquake types. The students passively listened to her explanations, answered some short questions, took notes or drew pictures as she directed them to. The following is an example of a conversation between Ms.Kanokpon and her students as she introduced the concept of the four types of volcanoes which included: Shield, Cinder, Steep and Composite Cone volcanoes. She also discussed the characteristics of each type of volcano based upon its resulting landform and associated eruption and lava flow. She used volcanic models to help explain the different types of volcanoes as she described their individual characteristics. The discourse went as follows:

Ms.Kanokpon: The first type of volcano is the shield volcano whose name is like a warrior's shield…What is the physical appearance of this volcano?

Students: It's flat.

Ms.Kanokpon: Yes, what about the profile?

Students: It's a broad profile

Ms.Kanokpon: Broad. How is a shield volcano formed? If you imagine fluid lava from a volcanic eruption, it obstructs the vent, doesn't it? But this type of volcano has a broad profile that means what about the lava?

Students: It flows very quickly

Ms.Kanokpon: Yes, the lava has to flow very quickly. Is the temperature of the lava high or low?

Students: High

Ms.Kanokpon: Lava with a high temperature can travel quickly very long distances. Therefore, the characteristics of a shield volcano are formed by hot lava that flows very quickly long distances. That gives shield volcanoes a broad profile. Some volcanoes in Hawaii cover a distance of hundreds of kilometers… Okay, write this down in your notebook. Lava with a high temperature that moves quickly over long distances makes a shield volcano with a

> broad profile. (*Students wrote this sentence in their notebooks*). Write down that high temperature makes lava that tends to be low in viscous that flow quickly over long distances and is slow to harden because of the high temperature. ….I will give you more details. There is not a serious explosive eruption. There are some pieces of rock ash that erupts out from the volcano. The last volcano is the Composite Cone…In this type there are many fissures for lava to come out. (Everyone writes down that Composite Cone volcanoes have a unique characteristic in that there are many vents and several ways the lava can be ejected *(repeat*) severe explosion (*repeat*) each explosion (*repeat*) may accumulate ash or lava (*repeat*)… (Second classroom observation from June 30, 2008)

When asked about her teaching practices, Ms. Kanokpon reflected upon her beliefs regarding student learning and her teaching practices. She stated that she believes that the teacher should give the students the key concepts and they should copy the notes she provides them and this will promote better student learning.

> …I do believe that students are unable to write down (*conclusion*s) by themselves. I need to summarize the key concepts on transparencies or else directly tell them. If they copy this information into their notebooks they will understand the Geological concepts better and it gives them a more permanent record in their notebooks of these concepts. I don't believe they could remember everything by merely sitting there and listening (Initial interview from July 28, 2008)

A notable point that came out of the previous conversation is that Ms. Kanokpon's teaching practices were primarily influenced by her belief that student discipline is very important in how students learn science because she believes that the teacher's explanations are essential for them to learn and that they learn best when they are the recipients of the information laid out by the teacher rather than them being the center or creator of the learning.

Interaction between the teacher and the students infrequently occurred in Ms. Kanokpon's classroom. It was a one-way street with her dominating the communication channels through explaining, story-telling, or giving examples related to a particular content. Two-way communication took place during her lectures when she asked the students questions and most of the questions usually required only low-order thinking skills such as recall. Such closed and subject-centered questions do not encourage student understanding and only encourage memorization. The class interaction between the teacher and the students on the idea of the location of volcanoes in Thailand went as follows:

Ms.Kanokpon: Alright have there ever been any volcanic eruptions in Thailand?

Students: Yes.

Ms.Kanokpon: Where?

Students: Panomrung

Ms.Kanokpon: Do you remember the Ring of Fire? …Can you remember which major continental plate makes up the Ring of Fire? As I told you and you have to remember. It's the Pacific plate. Which ocean is found on the Pacific plate?

Students: Pacific Ocean.

Ms.Kanokpon: Gases came out from volcanic eruptions and it is not LPG. It is carbon dioxide and what is CO2?

Students: Carbon monoxide

(Second classroom observation from June 30, 2008)

The discourse in this excerpt is an example of a pattern that emerged from observations of Ms. Kanokpon's teaching practices. The teacher used this method of teaching both to sustain her control of the lesson and to "transmit knowledge". It is seen that this type of practice limits the promotion and development of higher-order cognitive thinking skills. Her lessons also showed quite clearly that they are teacher dominated mostly through the use of verbal conversation controlled by the teacher. Any student participation consisted mostly of them just providing short answers to low level order questions. Ms. Kanokpon used the traditional method of lecture to give her students the information she felt was important for them to have regarding Geological concepts. This fit her belief that students learn best when they are simply told what to remember, record it in their notebooks and have very limited opportunity for interaction either with each other or with the teacher.

Rarely used hands-on experiments to teach the Geological content

Based upon classroom observations, it was obvious that hands-on experiments never occurred in Ms. Kanokpon's classroom. Although there are guidelines on how to include hands-on experiments on a particular Geological concept in the IPST textbook, Ms. Kanokpon did not follow those guidelines she just followed her own teaching method and discarded the idea of using experiments to support her students' learning of the Geological concepts. In a follow-up interview, Ms. Kanokpon admitted that she did not use experiments because she didn't feel they were compatible with the Geological content and she lacked the facilities and equipment to do the experiments. It was easier it seemed for her to just use the traditional method of lecture. She preferred to use different types of activities than experiments.

> …In geology, I don't use experiments but I search for information and use it to produce teaching and learning materials. I am not surprised that you have asked me why I don't use experiments, but I have my reasons. If there is an experiment in the IPST textbook I might use it to help me explain some concepts, but I never actually do the experiments in class. I have my own way of teaching that doesn't include experimentation. I believe that if students have knowledge, they can apply the knowledge using the scientific processes from the teaching and learning materials I have created for them…I think that experiments are a difficult way in which to gain scientific knowledge especially in

> Geology. There are many limitations such as equipment, devices, and chemical (Initial interview from July 28, 2008)

It is obvious that Ms. Kanokpon held strong to her belief that students learn Geological concepts better from a descriptive lecture approach rather than from being actively involved doing hands-on experiments or by even watching teacher lead demonstrations. She also remained fixated on the fact that there were many obstacles to doing experiments such as lack of facilities, lack of apparatus in order to accommodate such large classes as she taught. She compared the concepts in Geology to the ones in other fields of science such as optics in Physics and stated that topics in Physics needed to have experimentation for the students to understand them, but this was not necessary in Geology. Its concepts could easily be learned using her methods and teaching materials.

> …I also teach the concept of visible light in my physical science classes for students in grade 12. There are a lot of experiments. This is my understanding, my thought. Students need to do experiments regarding visible light in order for them to understand this difficult and abstract concept otherwise they *(the students)* don't understand it because they can't imagine it. But Geological concepts are not as abstract and I can use teaching and learning materials instead of experiments like models or multi-media presentations like videos that represent the concepts in Geology and Geological change and I thing this is a better method than using experimentation (Initial interview from July 28, 2008)

This quote explicitly illustrates that Ms.Kanokpan's teaching practices concentrated on video transmission approaches. Merely showing videos and displaying models without active student involvement is really not any different from her lecture based format and related pedagogies.

Task assignment on searching for information, in-class presentations and producing materials suitable to the Geological content

As was stated previously, Ms.Kanokpon did not use experiments when teaching the Geology content instead she believes that that giving the students tasks or assignments to work on was more suitable to the its content. She often directed her students to work in small groups to search for information and make presentations. She noted:

> …The process of experimentation takes quite a lot of time but producing teaching and learning materials can be done outside of class time …This (*scientific)* process can also occur when students are working searching for information. They have to generate conversation, give reasons, and ask questions…Actually, there are experiments that are related to Geology but I think searching for information is better. This is what I think especially when dealing with this kind of content (Initial interview from July 28, 2008)

For example, Ms.Kanokpon assigned the students to search for information on the following Geological topics, causes of tsunamis, protection from earthquakes, and protection from both volcanic eruptions and tsunamis. Generally, she assigned the task a week ahead of time so the students had time to prepare the content and to create some illustrations and materials that could be used to elaborate further on topics during their presentations. Each group did not research every topic, but instead they drew what predetermined topic they would cover from a selection created by the teacher. The students did not have to hand in any formal report, but they had to share their progress for their presentation ideas or the content they were going to include with their teacher so she could advice them on what to improve upon or even discard from their research.

When the students made their in-class presentations they mainly read directly from their reports with the teacher adding information as she deemed necessary. Some groups tried to use a story telling approach in order to make it more interesting for the audience. Ms.Kanokpon assigned the students to take notes during the presentations to encourage the students to pay attention and have a better understanding of the topic, but even with this they didn't seem to pay much attention to their peers. Ms.Kanokpon did not provide any opportunity for the students to discuss, ask questions, or give opinions on what was presented.

One task that Ms.Kanokpon gave her students was for them to generate a physical model that would represent the Geological time scales in the history of the Earth in order to highlight the characteristics of each Geological age. The stated goal of the activity was to foster "creative thinking through team working…by using recycled or inexpensive materials"(Initial interview from July 28, 2008). The task was assigned about a month prior to the class that discussed the idea of a Geologic time scale. Typically, the teacher had already set the topics consisting of the six major geologic ages and then had the students pick one of these predetermined topics. They were responsible to gather evidence of or to study the major events that occurred in their chosen period, the natural environment at that time, the living things that existed and the physical appearance of the Earth. They were instructed to build a model that would simplify what they had learned from their research and have it ready to support them in their in-class presentation. Each group chose a presenter to report what they had learned in their research and to explain their model. Other group members broke off from their own groups to learn from these "group experts". The students were given time to learn and to discuss the main points of each topic. In the mean time Ms.Kanokpon traveled from group to group observing the presentations and asking questions that checked the accuracy of the students' presentations. The students then returned to their original groups to share information among their other group members. They created a summary of the key ideas of each Geologic time period and made a concept map which was handed in for evaluation by the teacher. A quiz on all the topics presented by the groups was given at the end of the class so the students could get immediate feedback on how much they had learned form the group presentations.

In terms of student cooperation, they were able to work together to find information from various resources, to share ideas about the most affective arrangement of the content, and to make decisions about the presentation. In terms of student creativity, they exhibited their creativity through their models and in what format they chose for their presentations. In terms of student learning, they mostly used the Geology content that they found on the internet, in textbooks and other printed material resources. They might not necessarily understand the mechanisms or processes behind the Geological phenomena that they researched. For example the notion of Geological time periods relies heavily on the concept that the fossil remains found give clues to the period and the extracting of those clues is dependent upon being able to put a date to these fossils. These fossils also provide knowledge regarding the evolution and adaptation of living things from period to period. Simply having the students look for facts regarding the concept of Geological time may not clearly promote the underlying concepts. Making presentations of these facts may not either. Ms.Kanokpon barely raised the idea of integrating other science concepts into the topics she gave her students to research. There was no opportunity for them to go "beyond" the information surrounding them.

2. The Use of Teaching and Learning Materials

The use of physical models as the prominent teaching and learning material

Ms.Kanokpon usually used some three-dimensional objects which were commonly made of plaster of Paris to create different kinds of small-scale volcanoes. She also had some painted paper-mache volcanoes and some pop-up cardboard books with pictures of volcanoes. Because there was a shortage of teaching and learning materials regarding the topic of Geology, Ms.Kanokpon assigned her previous students to build models and she graded them as part of their class work. She collected these models for many years until she eventually had many examples to use with future students. She used these models to demonstrate in front of the class when she was explaining about the characteristics of different kinds of volcanoes. These models represented some features of volcanoes, especially the profile of volcanoes, their layers, or their craters. Ms.Kanokpon also used transparencies as classroom material aides.

The students were also given the task of creating a model of a specific Geological period such as the Jurassic, Cambrian, or Cretaceous that showed its specific characteristics and major events. The models took on many different formats such as drawings and paintings, dioramas or three dimensional pictures with moveable parts. For example a model of the Cretaceous period represented the idea of large scale mass extinction of many animals and plant species based upon one of the theories that scientists theorize caused this mass extinction, a catastrophic event such as a massive asteroid impact. The students showed this major event in the model by positioning miniature objects like dinosaurs and an asteroid. These finished models were then presented to the class.

Ms. Kanokpon expressed her point of view on the task of having students build teaching and learning materials for her and themselves as:

> …Creating teaching and learning materials requires the use of the learning processes. If there are not enough materials, I assign students to make them. It allows me to assess what they have learned while at the same time creating many useful teaching materials. The same materials are not created each year because I learn from the problems that occur in previous years. I have made a lot of improvements in this assigned task (Initial interview from July 28, 2008)

In addition to using student created models, Ms.Kanokpon also showed videos that relate to the Geological content she taught. She shared these videos at the end of the unit using them as a way of reviewing all the key knowledge points the students should have gained. Generally, these videos were from the Department of Mineral Resources and Ministry of Natural Resources and Environment who play a prominent role in promoting the study of Geology by providing non-commercial teaching and learning materials for schools.

3. Assessments and Evaluations

Ms.Kanokpon relied on a variety of different types of assessments such as student worksheets, student notebooks, authentic assessments on student performance, and traditional paper and pencil tests. Each method was used in different occasions with respect to the content and activities of each unit. However, paper and pencil tests were used at the end of the lesson and the end of the semester.

Student worksheets and notebooks

Student worksheets were used to assess the students' understanding at the end of every unit. Typically, the sheets were of a fill-in-the-blank and short-answer format. Most of the questions mainly assessed the cognitive domains regarding the Geology content. Ms.Kanokpon usually assigned these questions as homework and had the students hand them in at a later time for assessment.

The students' notebooks were included in Ms.Kanokpon's assessment strategies. She required the students to hand in their notebooks every week and she believed it was their responsibility to have a neat and organized notebook complete with all the important content presented in class.

Authentic assessment methods of student performances

The format of authentic assessment methods included the activities that involved the students making presentations or their building of models. The concept maps the students created during the presentation task was another example of an authentic assessment method. Ms.Kanokpon usually used an assessment program based on teacher-developed criteria for the students to assess their classmates when they presented their group work. She informed her students about the criteria prior to their presentations, which usually included: how well they covered the assigned content, their ability to transfer their information to their audience, what learning resources they used, creativity, team cooperation, responsibility, ethnicity, and how good their model was. However, in the follow-up interview she expressed her belief that using peer assessment could “make them uncomfortable to score their friend’s performance” (Initial interview from July 28, 2008). For this reason she sometimes avoided using peer assessment in some activities.

4. Using an Integrated Curriculum

Using analogies of every-life experiences to represent integration of other science content knowledge to understand Geological phenomena through the posing of short questions

Many Geological processes relate closely to other science subjects and every day life analogies can better enable the learning of the Geological processes. For example, from the classroom observations on the topic of the types of volcanoes, Ms.Kanokpon attempted to ask some questions that had the students think about the relationship that exists between temperature and the velocity of lava with volcanic profile. She used the analogy of how condensed milk at room temperature flows much more quickly than the same milk that was in the fridge. The use of this analogy gave her students the opportunity to relate the idea of temperature and lava flow to something they have experienced in their every day life. Another example of an every day analogy is the use of convection currents in cooking and how this relates to the idea of plate moment in plate tectonics. It was apparent to this researcher that Ms.Kanokpon frequently used analogies from every day life experiences rather than doing hands-on activities or experiments to integrate related science subjects. She shared her experiences of using analogies along with questions to integrate other science concepts with Geology concepts through a conversation in the second meeting. The reason for using analogies with short-answer questions was a lack of time for any time-consuming experimentation or other hands-on activities in classroom because there is a limited amount of time in which to cover all the content.

> …I need to teach about convection currents as well. I give the example of dropping meat into warm water. When the water is boiling, the heat brings the meat up to the surface of the water until it reaches a cooler area on the surface it then sinks down to the bottom. When it

> receives heat from the gas below it goes up again. You can not pick up any of the meat while it is in the boiling water. It will circle continuously to moving up and down. This is the process of a convection current. Students have to imagine if we cannot do an experiment. I have to tell you (*the group members*), sometimes students actually don't do an experiment. I tell that if we have time, we will observe the convection currents that make continental plates move and what affect these have on everything on the planet (Second CAR group meeting from December 13, 2008)

This quote reflected some of the struggles Ms.Kanokpon has about using experimentation and her use of questions about day-to-day experiences about content integration instead. It can be seen that she predominantly interconnected the notion of heat and energy with the cause of different types of volcano by asking questions, although the questions were mainly yes-no questions or ones with two specific answers (high or low temperature) or some recall questions which probably did not challenge their knowledge effectively or encourage the students to think critically.

Uncertain content knowledge of related science concepts to explain Geological phenomena

From the classroom observations, Ms.Kanokpon expressed her discomfort with her lack of background knowledge on Physics content. When some students made a presentation about tsunami waves and they stated that a wave that starts way out in the ocean can become a gigantic wave when it reaches the shoreline. Ms.Kanokpon asked why this happened and none of the students responded to her question. Ms.Kanokpon did not feel confident in her abilities to answer the question herself so she directed them to find more details outside class time. The discourse in the class went as follows:

> …When it (*the tsunami wave*) is in the (*deep*) ocean it forms only a small hump of about a few feet ... but by the time this wave reaches the shore, it has become huge. Anybody want to share ideas as to why this

> happens…I will start for you. I wonder why it is like that. … Anybody? ... I'd like you to search more. I won't answer this question. You could try to find out using some Physics concepts, or ask other (Physics) teachers, and give me the reasons why a tsunami travels at a very high speed, but only forms a small hump in deep ocean water but in shallow water near a coastline, a tsunami slows down but forms large destructive waves. Search this idea. I won't answer it and it won't be on the test, but I want you to find out more because maybe you might see it on an ONET or ANET exam (Third classroom observation from July 7, 2008)

This discourse excerpt with the students revealed reluctance on the part of Ms. Kanokpon to integrate particular concepts that she is unsure of. She preferred to keep herself out of trouble by telling the students to find the answer themselves but she did not have any discussion on this topic later. Although a follow-up interview indicated that she had allowed the students to ask a Physics teacher to explain it to them. It was obvious that she was not comfortable to talk about content in which she had insufficient content knowledge or to discuss other science subjects that were beyond her expertise.

In conclusion, in the first semester Ms. Kanokpon predominately used a teacher-centered pedagogical approach which used practices that were based upon her beliefs in what were the best methods to use to teach and learn science. She saw her role as a "the transmitter of knowledge." This was demonstrated most clearly in her use of lecture style practices and her demand that students take extensive lecture notes. Experiments were infrequently done and the main task students were given was to research certain dictated topics and create models based upon this research. Students were asked to do presentations of their group's research. The anxiety and concern about the pressure to cover all the concepts as required in the national curriculum standard had great influence on her teaching practices. This major concern had her abandon any ideas of doing time consuming activities or using a more student-centered approach. She used teacher dominant methods and text-based assignments so she could meet the required content needed to be covered in the curriculum. The assessment and evaluation of the students' learning relied mostly on student worksheets which contained mostly cognitive questions. Student performances in groups and presentations were assessed by using peer-assessment and by using teacher-developed criteria. In terms of using an integrated curriculum, Ms.Kanokpon exhibited her awareness of the integration of related science concepts with geology contents in her use of short answer questions and analogies. However, she also revealed her uncertainty of related science concepts that were out of her field of expertise.

Research Question II: How do Geology teachers change their teaching practices after participating in the collaborative action research group (CAR)?

There were three classroom observations conducted in the second semester, but because Ms.Kanokpon's classes was scheduled during the first period it was often affected by morning school activities and subsequently often started late, sometimes by even 30 minutes. This happened in two occasions so she was unable to follow her initial lesson plans as she did not have the full 100 minutes. Ms.Kanokpon spent more time teaching the Geological topics as compared to the time she took to teach the Astronomy ones which meant she started earlier than her colleagues. She began to teach Geology before the mid-term exams and continued to teach them immediately after the exams so she should have had enough time to cover all the content areas. But there were several school events that occurred during the semester and as a result she was unable to follow all her lesson plans and sometimes had to wrap up classes early to make them up later.

The researcher conducted post-class interviews, examined the teachers' lesson plans, and used the CAR group meetings to better understand Ms.Kanokpon's teaching practices which were categorized into several themes as below.

1. Teaching and Learning Processes

Teacher-dominated teaching process but providing students with more opportunities of inquiring their thinking through class discussion

In the second semester, Ms. Kanokpon still mainly dominated the class by telling stories and demanding that her students take notes in her lessons. She continued to expect her students to learn all the content outlined in the curriculum. However, she did make an effort to have more two-way conversations with her students in class. She designed her lesson on how Geologists discovered the Earth's structure to include a probing of her student's prior knowledge of this topic. Geologists have used seismic wave action to uncover information about the structures beneath the Earth's surface. When she asked how she could uncover any prior knowledge her students may have on this idea to the CAR group, they suggested that she "pull in" her students by writing on the board any answers the groups may suggest whether they be correct or not. She could then add explanations and facts to their list. She could provide them with support by urging them to explain their suggestions and help them back them up with scientific knowledge.

There were some small changes in Ms. Kanokpon's teaching methods in the second semester. She did move a little away from her dominant classroom role by allowing her students to participate in more discussion. She created a more two-way communication friendly classroom environment. There was a shift in the teacher-dominated, one-way communication methodology to more of a two-way communication approach. She designed her opening activity to enable her to probe at the students' prior knowledge. They were instructed to answer questions on the possible origins of earthquakes. As the activity progressed, various answers came from the students and the teacher noted all of them on the board. There was conversation between the students and the teacher in order to clarify ideas and to promote student participation in the classroom as well as to examine students' prior knowledge on what they were going to study.

Efforts to involve experiments in the lesson

In the first semester, Ms. Kanokpon believed that doing experiments did not fit well with the Geological content, but in the second semester she made an attempt to include an experiment, the one about the convection current mechanisms of plate movement. At one of the CAR group meetings, the researcher explained one example of a hands-on activity she used to investigate the mechanisms of convection current to the teachers. Ms. Kanokpon adapted parts of the example in her lesson plan. She planned to use the demonstration of: a glass container filled with water placed on top of an alcohol burner that she would place in front of the class. She would then drop a piece of paper onto the water surface while the water was boiling. The intention of this activity would be to provide students with a chance to observe what would happen to this piece of paper. The students would need to use scientific process skills to draw a conclusion regarding this activity and to make connections with it to the Geological process. However in classroom practice, an unintended situation happened because she was not well prepared. It took too long for the water to boil and she ran out of time. She ended up having to explain the concept by using the analogy of cooking food by adding ingredients to hot boiled water or soup. All the ingredients will go upward to the surface and eventually sink to the bottom. An example of the teacher and the students' discourse that occurred is as follows:

Ms. Kanokpon: You have learned that the Earth's crust is not joined together in one plate, but instead it looks like an egg shell that is broken into little pieces. The broken tectonic plates consist of major and minor plates like these (*pointing to the picture*). If I cut this paper into two pieces and drop it in this a beaker filled with water and I heat the water, what would happen? What is the paper modeling?

Students: Earth's crust.

Ms. Kanokpon: Yes, the Earth's crust. I place the pieces of paper on the water's surface and heat it. What will be changed?

Some of you hypothesize that the pieces of paper are going to break apart. What about other group ideas?

Students: The water will boil and the paper will bend.

Ms.Kanokpon: As you see now, is paper moving?

Students: Not yet.

Ms.Kanokpon: The paper does not move and is staying still.

(*Water in the beaker did not boil and nothing was moving so Ms. Kanokpon used the analogy of cooking in boiled water*)

Ms. Kanokpon: If you can imagine water in a pot on a stove. When you put meat into regular water, not boiled, what happens to the meat?

Students: It will go down.

Ms. Kanokpon: It will go downward to the bottom of the pot and what happens when the water starts to boil?

Students: The meat will float up to the surface.

Ms. Kanokpon: That's right. Can you scoop it up easily?

Students: No.

Ms. Kanokpon: Because when it comes up, it will sink to the bottom again, right. Then it will attract more heat at the bottom, it will go upwards again. What causes the meat to float?

Students: Heat and pressure.

Ms. Kanokpon: … temperature causes the motion of water. It conducts heat and makes these two pieces move. Thus, what causes the Earth's crust to move and then can cause an earthquake?

Students: Heat

(First classroom observation from January 8, 2009)

She dealt with this problem by asking the students questions and letting them think of a hypothesis, even though the students had no time to do any hands-on experiments. Ms.Kanokpon reflected about her thoughts after doing the activity which did not happen the way she expected. Time constraint was an important contextual factor that caused her to be unable to plan completely and to use the experiment to maximize her students' understanding of tectonic movement. After the lesson, Ms. Kanokpon shared her frustrations regarding her attempt to have a well planned activity and the time limitations she experienced in doing this hands-on activity as:

> …I have a lot of things to improve upon. I was not satisfied with the experiment. It was difficult for the students to observe. And the students came very late so I could not stick to my lesson plan…I could not do much in the time …The two-period lesson plan became a one period one (Initial interview from January 8, 2009)

> …It was problematic. I think I might not use this demonstration again. I might give the students an example of the experiment and let them do a comparison. Since, the demonstration did not work out I solved the problem by giving them the analogy of boiling water in a pot. Everyone knows that there is the heat at the bottom of a heated pot. They can understand this idea without seeing it (Initial interview from January 8, 2009).

2. The Use of Teaching and Learning Materials

The use of computer multimedia to discuss content with students

In the second semester, Ms. Kanokpon made use of video clips and cartoon animations that she down-loaded from an internet database to increase her students' interest levels and their participation in class discussions. She introduced her students to the notion of volcanic activity by using virtual computer animations that she displayed on a television screen. She asked the students to state the causes of volcanic activity and what volcanic eruptions look like. She also utilized video clips that discussed the consequences of earthquakes, including those on various man-made structures, blackouts, the chaos that occurs among people and the destruction of objects.

Ms.Kanokpon: From what you have seen in the video clips, what causes a lot of destruction?

Students: Earthquakes

Ms.Kanokpon: What are some causes of an earthquake?

Students: Motions of fault lines

Ms.Kanokpon: Yes. As you have learned they are caused from the movement of tectonic plates

(Initial classroom observation from January 8, 2009)

The students paid much more attention to the whole class discussion about what they had seen when the teacher displayed video clips or examples of virtual animation, especially those that exhibited Geological phenomena and their aftermath. The use of these teaching and learning materials also served as an introduction to the study of Geological phenomenon in terms of the mechanisms that drive them which would be discussed in future lessons.

The infrequent use of models representing Geological phenomena due to time limitations

In the second semester, Ms. Kanokpon used the same models she incorporated into her lessons of the first semester because she had not assigned her students to produce any more. During her lessons on types of volcanoes, she displayed the old student created models. These models mostly focused on the physical appearance of volcanoes such as their height, external profile, or distance in base. In the second CAR group meeting, she shared her viewpoint that she would like to use other types of models, ones she had not previously used in her classroom and was looking for some suggestions. Ms. Sunee shared her lesson plan about the processes of plate tectonic movement in which she used a variety of everyday materials such as sliding bricks, or plastercine to show the shifting of tectonic plates.

Ms. Kanokpon commented that this activity could take a long time in a real classroom and as a result she might not cover all the expected content on time.

> …Personally, I think it is long activity. You might not be able to cover all the necessary content and I might end up having to tutor. You might briefly compare the experiment the students did in the lower secondary levels about phase change… I think you could connect that experiment to your activity. I don't think the students should do this activity because they have done it already or a similar one perhaps. Maybe it would save time to just review the concept." (Second CAR group meeting from December 13, 2008)

Ms. Kanokpon did use a model, the slinky to elaborate for her students on wave propagation. The students were allowed to manipulate the slinky in order to observe the properties of waves which included longitudinal and transverse waves by moving the slinky backwards and forwards in their hands. It served as tool to demonstrate actual waves generated throughout the exterior of the Earth and the differences between the two types of seismic waves. As well Ms. Kanokpon used the water boiling analogy to represent the idea of convection currents. These reflected her effort to engage students in activities even though her personal opinion that teaching Geology with hands-on activities is time-consuming and eats into her ability to cover the required content still persisted.

Overall, there was no considerable shift of using different teaching materials in the second semester because Ms.Kanokopon encountered a shortage of teaching and learning materials. She utilized almost all of the same materials from previous semesters even though she had learned of other teachers' experiences of using other types of teaching and learning materials from the CAR group meetings. She failed to incorporate any of these news ideas into her own teaching practices.

3. Assessment and Evaluation

In the second semester, Ms. Kanokpon used similar worksheets to the ones she used in the first semester to assess the students' understanding at the conclusion of each chapter. The sheets were scored with respect to the students' understanding and the majority of the questions assessed the cognitive domain and not the psychomotor or affective domain. She used the students' notebooks to evaluate how well the students paid attention in class and how responsibly they took notes on what she presented in class. In spite of the fact that she repeated a lot of the assessment and evaluation techniques she used in the first semester in the second semester, there were some significant changes to her practices and these are discussed below:

Developing worksheets to diagnose student knowledge

Ms. Kanokpon put an effort into developing several new worksheets to assess her students' understanding of science content that was related to the Geological content. Using the suggestions of the CAR group members regarding the examination of students' basic knowledge of other related science content prior to the start of the lesson, Ms. Kanokpon designed her lesson plan using worksheets that assessed ideas related to the origin of the Earth, the evolution of the Earth, and the chemical compositions of the Earth. The researcher provided her with support so Ms. Kanokpon could design these new worksheets. The worksheets were a typical combination of open-ended questions (requiring student explanation) and fill-in-the-blank sections. Example questions included: "What do you think about the origin of the solar system and the Earth?", or "What did the Earth look like when it was first formed and solidified?" (Taken directly from the student worksheets). Each question was evaluated by using a rubric and these were categorized into four groups: sound understanding, partial understanding, alternative understanding, and no answer at all. These rubrics were developed from suggestions made by the CAR group to deeply diagnosis the level of student understanding, but not to judge right and wrong by giving scores.

Ms. Kanokpon put in an effort into recognizing her students' prior knowledge by using a diagnostic test that was discussed at a CAR meeting. She did not develop a diagnostic test for every lesson to elicit the students' prior knowledge due to lack of time to plan. In some occasions, she posed questions for the students to examine their understanding during the lesson.

The use of authentic assessment, self-assessment and peer-assessment for evaluating student performance during presentations

Ms. Kanokpon planned to use self and peer-assessment for her students to assess their group work for presentations. She developed the criterion and rubrics that would be used and she informed her students about both prior to their presentations. The criteria were: how correct was their content, how well did they express their knowledge, did they identify their resources, the language of their presentation and how well did they work as a group. Each criterion was scored using four categories from one to four. Ms. Kanokpon allowed her students to assess their own presentations and other group presentations as well. She also assessed her students during their presentations and she monitored and evaluated her students' use of information from various resources or internet databases.

> …I observed their presentations and evaluated the information they shared as a way of grading their performance. It gave me an advantage as I could see how well they were working together (Second interview from January 15, 2009)

> …They know where to find (*information*). They do well in this area because they all know how to log onto websites. For this reason, I wanted them to list their learning resources so I know which websites they visited. They've all got excellent computer skills. (Second interview from January 15, 2009)

Ms.Kanokpon did not use other types of assessment to monitor her students' understanding from the presentations. Unlike in the presentations of the previous semester, Ms.Kanokpon "made a mistake by not letting the students take notes" (Second interview from January 15, 2009) or create concept maps regarding their understanding of the material presented. A shortage of time was stated as the main reason for eliminating some of her previously used assessment techniques.

4. Using an Integrated Curriculum

Recognition of the integration of related science content knowledge with Geology in the teachers' lesson plans

In the second CAR group meeting, Ms. Kanokpon showed her recognition of the importance of integrating related science knowledge with Geological content by sharing her teaching practices about the structure of the Earth. It can be seen that she explicitly integrated Geological concept into other science subjects, especially the concept about the chemical elements contained in each layer of the Earth. She stated:

> …The Structure of the Earth can be seen as chemical composition. It is basic chemical knowledge that each layer contains different kinds of elements and these elements relate to the origin of the Earth. When the Earth was cooled, the heavy metals sank into the core. If the students know the process that caused the structure of the Earth, then they understand the idea that heavy metals went into the core. This all relates back to chemistry and the concept of the major elements and their production as it relates to the structure of the Earth. (Second CAR group meeting from December 13, 2008)

Another example was the integration of wave concepts to explain more about the structure of the Earth. She explained:

> …To study the structure of the Earth, geologists cannot dig a hole deep enough into its center so I ask the students how they can find out about what is inside the Earth. If the students answer using satellites or

> drill a hole into the center, I explain that this cannot be done because the deepest hole that has been dug is about 40 kilometers. I tell them that Geologists use seismic waves instead. (Second CAR group meeting from December 13, 2008)

Bringing ideas to the CAR group meeting helped Ms. Kanokpon learn from the comments and suggestions of the group members. For example in the integration of wave concepts, the group members suggested some further activities to explain how Geologists study the structure of the Earth. They suggested that each group of students should investigate and report back evidence that would support their ideas and then the whole class could discuss their evidence eventually agreeing or disagreeing with their ideas. The teacher could then play more of a facilitator's role by adding to the information presented by the students regarding the idea that seismic waves are used to identify the structure of the Earth. This suggestion relies heavily on the idea that students could integrate any basic knowledge they may have regarding the interior structures of the Earth and at the same time covering the Nature of Science in sub-strand 8 of the National Science Curriculum which aims to make students base decisions on already existing evidence.

Ms. Kanokpon did not only take suggestions from the CAR group regarding how to integrate concepts from other areas of science, she also contributed her own ideas to help another teacher in the group. For example she suggested her idea of integrating the concept of chemical elements and how they relate to the Geological concept regarding the different layers of the Earth to Ms. Sunee. Rather than identifying the Earth's structures by physical properties, particularly the states of matters that define the solid crust, molten magma and the solid core, Ms. Kanokpon suggested using the chemical composition of each of the layers instead. Each chemical composition of each layer has distinct properties particularly density that causes the arrangement of the layers inside the Earth. This is evidence, that by collaborating with the CAR group, teachers were able to recognize the existence and importance of the integration of other science content in Geology.

Integration of related science concepts with Geological concepts mostly through use of the lecture-based method and superficial explanation of related science concepts to elaborate on Geological concepts

Although Ms. Kanokpon integrated some Geological concepts with some Physics concepts in order to explain further the mechanisms involved in Geological phenomena, she mainly dictated the necessary information directly to her students and did not engage them in any way in which to connect this knowledge themselves. For example in her explanation regarding the mechanisms that create earthquakes, she described to her students that earthquakes are mainly caused from the transfer of energy from the potential energy that accumulates in the rock layers that is suddenly released affecting many adjoining areas.

> …Let's write. Earthquakes are generated from the movement of plates which rapidly transfer potential energy. Umm…we're talking about potential energy. You've learned that potential energy is the energy accumulated in objects. Thus (*the energy*) transfer is much stronger from a severe collision and transfers much energy as well, right. (Initial classroom observation from January 8, 2009)

Some Geological content was superficially described with respect to related science concepts such as Ms. Kanokpon's explanation of tectonic plate movement by using the concept of convection currents in cooking with boiling water. She explained that heat was the cause of convection currents and therefore plate movement. Instead of describing the mechanism of convection currents which relies on the relationship between temperature and density, she explained that the underneath the crust it is hot and it contains fluid magma which makes the crust move. She described as:

> …Temperature makes water move and generate convection currents and also make two plates move. The cause of tectonic movements and earthquakes is from…heat energy underneath the Earth's crust. You've learned that the crust is solid and inside the crust is…liquid which is magma, right…so magma plays an important part in

causing the crust to move." (Initial classroom observation from January 8, 2008)

From this quote, Ms. Kanokpon held a misconception regarding whether it is heat or temperature that causes water to move. She used the word "temperature" to explain why tectonic plates can move when in fact temperature is the measure of the heat energy, but heat energy itself drives the motion of the water when it expands and moves upward. Although, this seems a minor mistake of miss-using a scientific word the teacher should be aware of using words with close meanings to explain a complicated concept.

Although the researcher had introduced the example of the activities related to convection currents in the first CAR group meeting, Ms. Kanokpon decided to use the methods of integration that she was familiar with and believed that her students would get a better understanding using her methods.

Utilizing interactive questions with students and teacher-demonstrations to increase their recognition of integration rather than doing time-consuming hands-on activities.

Ms.Kanokpon continued to state her belief that she did not use hands-on experiments to integrate Geology with other science disciplines because to do so would require time she did not have. Instead she revised her questioning techniques to use questions on student worksheets that would elicit her students' basic knowledge of related science concepts. She believed that:

> …Learning activities are about asking questions. It does not have details of the questions on it (*lesson plan*)…Integration of other science concepts by using the experiments such as the ones on faults found in the IPST textbook, well I do not want to do them…. (Second interview from October 18, 2009)

> …Frankly, it's the time limitations, so teaching is about explaining with a little bit of discussion. It's impossible to do experiments and finish everything we have to. No way. I like using questions. (Initial interview from January 8, 2009)

From the excerpts it was clear that Ms. Kanokpon was reluctant to implement hands-on experimentation to engage her students in learning. Rather she used demonstrations in front of the class such as the time she demonstrated the propagation of seismic waves using a slinky. . For example, she demonstrated the propagations of seismic wave which composted of longitudinal wave (P-wave) and transverse wave (S-wave) by using the movement of Slinky. The students were allowed to investigate the properties of the two waves longitudinal (P waves) and transversal (S waves) associated with seismic waves and to discuss the differences between them.

In summary, in the second semester, Ms. Kanokpon changed her teaching practices in some aspects according to what she learned from the CAR group meetings such as examining students' prior knowledge or employing hands-on activities. However she still utilized some very traditional teaching styles and practices consistent with her beliefs about teaching and learning science. She was content to allow the students to become engaged in the lessons through discussion, investigation or demonstrations and by her use of video clips and virtual computer animation. The students showed more interest in her lessons and participated more actively in discussions all of which did not occur in the first semester. Although she still utilized the lecture method and demanded the students take notes, perform her assigned tasks and presentations. She did begin to develop worksheets to diagnose her students' understandings prior to her lessons. In terms of using an integrated curriculum, Ms. Kanokpon tended to improve her teaching practices by using questions related to other science contents rather than using hands-on experiments. However, she also designed her lessons plan to include some demonstrations which integrated related science concepts with the Geological content. Overall Ms. Kanokpon demonstrated a small change of her practices from participating in the CAR in terms of learning useful activities and recognizing students' prior knowledge.

Her reflection on the limitations of time and her personal belief on how to best teach Geology continue to influence her practices and do not allow her to completely achieve an integrated curriculum in a real classroom.

Case Three: Ms. Sunee (Laliya School)

Teacher's Background

There were two teachers, Ms.Sunee and a colleague that were responsible to teach sub-strand 6 and 7. Her colleague taught all the students in the science-oriented program and Ms.Sunee taught the five classes of non-science oriented students. Her expertise in Geology was limited to an introductory course she took while pursuing her Master's Degree. She never attended any workshops related to Geology.

Unlike other schools, all of the Grade 11 students at Laliya had to study Geology in the second semester. The timetable had Geology scheduled as three periods per week, one on Mondays and a double on Tuesdays. This was actually more time than other schools which only had two periods of Geology scheduled per week. The students studied Astronomy in the first half of the second semester and the rest of the time was spent studying Geology.

Context of the Students

In the second semester, there were 25 non-science oriented students in the computer program and one-sixth of these students were female. Although the students were in the computer program, they were not actually interested in or had any particular computer skills that qualified them to be in this program. In fact, the school offered this program for students who were unable to study in other programs. These students were characterized as having learning, discipline and attendance problems. For example, the number of students who attended the Geology class that was scheduled for the last period of the day was usually between 12 and 17 with many other refusing to attend. As well many of the male students in class were members of the school's football team which meant they were often out of class so they could participate in competitions. The teacher therefore never knew how many students would be in class from day to day.

In terms of their learning achievement, the students performed fairly low in many subjects such as Mathematics, English Language and science. Some of them did not pass the standard score levels in some of their subjects in the last semester. Their parents were informed of their low achievement levels and were brought in to discuss this issue with the teachers.

Classroom Setting

The classroom was pretty large with dozens of tables and chairs arranged in parallel rows. Unlike in Ms.Pimpon's and Ms.Kanokpon's classrooms, the students in Ms.Sunee's classroom sat in pairs at one desk all facing the same direction. The students typically sat in pairs during lessons unless there was an activity that required them to study in larger groups. As girls were the minority in the class, they always sat together in pairs and whenever there was group work they make their groups bigger by adding more girls and the boys did the same. Ms.Sunee originally set the pairs and groups as mixed-gendered but the students did not follow her seating arrangement and created their own. Classroom diagram is presented below.

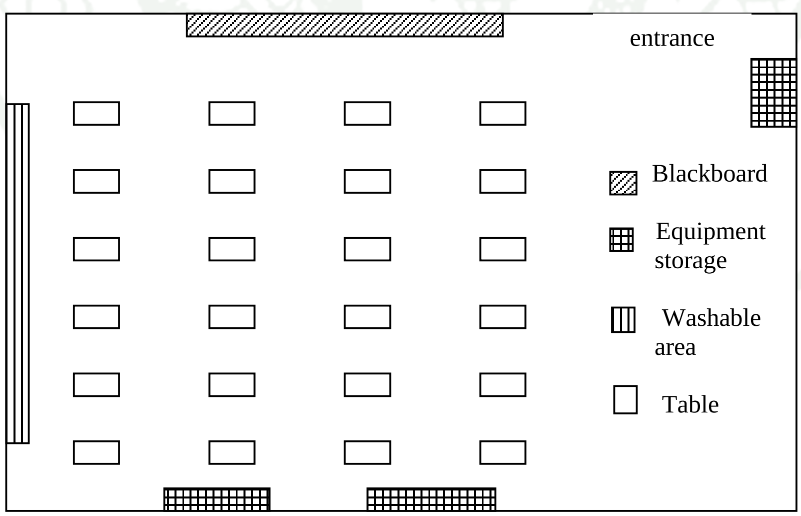


Figure 4.3 Layout of Ms.Sunee's Classroom

The classroom contained an LCD player and screen that allowed Ms.Sunee to project documents or objects large enough for all the students to be able to see at a time. She used this teaching tool in every period. In the room there was a secured cupboard that contained a microphone and VCD player, but in order to use these the teacher had to make arrangements with a technician first who would set it all before the period started. It could not be used spontaneously by anyone. The back of the classroom contained large storage cabinets for scientific equipment such as a balances, alcohol burners, test tubes, graduated cylinders, thermometers, beakers, flasks, magnifying glasses, clamps, sets of already classified rock specimens. Any necessary chemical substances were locked in a separate room.

Research Question I: How do Geology teachers' actual teaching practices compare to the integrated curriculum's suggested teaching practices?

Because Ms.Sunee only started her participation in the study in the second semester, the researcher never observed her in the first semester. Thus the researcher had no data from classroom observations instead she conducted interviews, studied Ms.Sunee's lesson plans and conversations during group meetings to understand her teaching practices and to answer the first research question. The themes that emerged from the data were interpreted through four major topics: teaching and learning processes, the use of teaching and learning materials, assessment and evaluation, and using an integrated curriculum.

1. Teaching and Learning Processes

Frequent use of the lecture-based method and reading printed materials for teaching Geology due to time limitations

Ms.Sunee frequently relied on the traditional lecture-based teaching method in order to explain the Geological content following the information provided in the IPST textbook. The students passively received this knowledge from the teacher. From the interview, she stated:

> …I typically explain concepts for them and let them do experiments sometimes … It's the time limitation, shortage of time.

> Occasionally, I have to discard experiments and substitute them with teacher demonstrations … We have a total of 20 weeks *(for teaching)* but we never actually get that number because classes are taken up by mid-term and final exams and there are many school activities that take place during class time. All this affects (my teaching) somehow. I develop reading sheets to recap key concepts for students to read themselves. I try to give them all the necessary knowledge … If time was more available, the students would be allowed to perform more activities. It might be a group assignment or group task like building learning materials such as structure of the Earth models. I do assign them to collect news with relevance to the occurrence of earthquakes that involve destruction and highlight any aftermaths…(Initial interview from November 12, 2008)

From this excerpt, it is obvious that, in spite of having concerns that she should use more student-centered learning techniques such as hands-on activities time limitations was a major issue which put pressure upon Ms.Sunee to complete all the content and thus she chose to use the more teacher-centered approach, the lecture, to ensure she covered all the material. If she had the time, she would encourage the students' engagement in hands-on activities to help them gain perhaps better insight into Geological knowledge. She did make sure that the researcher understood that her weak education background in Geology did not affect her beliefs regarding appropriate teaching methods for teaching science. The discourse of the interview went as follows:

Researcher: Is your weak educational background in Geology an issue for you?

Ms. Sunee: No. I have been teaching eighth grade students in science which covers some Geological content that is relevant *(to upper secondary levels*).

Researcher: When you lecture the students, is this method congruent with your belief about teaching science as the transmitting of knowledge?

Ms. Sunee: Of course not. If students could do hands-on activity, they will be able to learn better than simply by rote learning.

(Initial interview from November 12, 2008)

In situations when even the time for lectures was cut short, students were assigned to read from given printed sheets prepared by the teacher. These given sheets consisted of summarized lists of key concepts that the teachers wanted the students to know. The students only read the sheets and then took an exam after the assignment without any discussion on what they had read. As Ms.Sunee stated:

> …They have to read *(the print materials)* by themselves … usually close to term examinations … I give them the reading sheets and then they have to take the exams … If it is a two-period class, one period is for reading and the other to take the exam, or I assign the sheets as out-of-class reading giving them a few days to complete them and then they take the exam the next week… It all depends on the availability of time. Sometimes I assign the students to search for more information themselves and then have them share their work with their friends in the classroom. It depends on the situation. I sometimes make a worksheet of some significant concepts for them to read by themselves and then I also wrap up some ideas in the class. (Initial interview from November 12, 2008)

Ms.Sunee put her emphasis on giving her students knowledge in class but there was an absence of discussion between her and the students and the students with each other. It can be pointed out that this type of activity did not change between her original method and what the students were reading. Knowledge was transmitted to the students by different means of media in an effort to cover all the content in a limited amount of time. Ms.Sunee realized that her teaching practices might not be good for the students in terms of enriching their learning processes. She stated "It was a way to give knowledge to them, but we did not use any processes to do it. This approach can be changed depending upon how much time is available." (Initial interview from November 12, 2008). <u>This approach explicitly contradicts what is</u>

called for in a student-centered regime, but the lack of time was an important constraint to her adopting this new educational reform. Further, it is evident that the dominance of the lecture methodology to disperse Geological content using text-based resources would not provide a pathway for the interconnections of relevant knowledge to the students and to allow them to observe science as an integral part.

Using hands-on activities when there is enough time and equipment and if not using teacher-led demonstrations instead

Hands-on experiments took place in the class whenever time and equipment was available. Most of the activities were available in the IPST textbook which included guidelines for some interesting experiments. The reason for relying on the IPST guidelines as the major resource was because they were in accordance with the National Science Curriculum Standards. Although, Ms. Sunee encountered an absence of material resources such as ready-made tool kits for doing experiments provided by IPST, she did find alternative materials to replace them. For example, the experiment in the textbook about fault lines and plate movement suggests using a tool kit of a square frame of two blocks with the blocks able to move past each other. Instead Ms. Sunee modified plain blocks of wood in attempt to demonstrate the process of plate movement. The students observed the changing plate movement, presented data to the class, shared ideas with other groups, and drew a conclusion from the experiment. Ms.Sunee pointed out the goal of using this experiment as follows:

> …Student understanding would better occur. That means, the lecture is an abstract … it is better to allow students to observe using teaching and learning materials rather than always listening to you talk and talk a thousand times. It will promote the summarization of knowledge better. Students are permitted to perform an activity despite the fact we could not generate or offer the real phenomena or occurrence in a classroom setting. Yet, experimentation can give them an opportunity to observe it just the same. (Initial interview from November 12, 2008)

> …Students could practice their scientific skills *(reporting data or drawing conclusions)* but it is not a fully complete process. Generally, they practice making observations, reporting data, and drawing conclusions … There is discussion when I ask questions for discussion. Although the students did not discuss in small groups but typically as a whole class, discussion would occur before a conclusion is reached (Initial Interview from November 12, 2008)

From the above statements by Ms.Sunee it seems she aims to promote student learning by offering hands-on activities as often as she can because she thinks that the students will be able to learn better when they interact with materials and are given an opportunity to participate in the lesson activity, rather than being passive recipients of knowledge. However, the scientific process skills are not completely acknowledged when the students are doing experiments as only a few processes are emphasized like observing, recording data and making conclusions.

In light of the difference in her students' abilities, Ms.Sunee believed that by using the procedures of an experiment the students could learn from participating in this type of activity no matter what their learning ability levels and could perform the experiments. Not-exceptional students in the non-science oriented program might need more time and effort to find understand than students in the science oriented program especially if the non-science students have a low interest and curiosity regarding science. The excerpt from the interview went as follows:

Researcher: Are there any problems with using experiments?

Ms. Sunee: Students' lack of interest and low level of curiosity because they are non-science oriented students.

Researcher: Is it because of the non-science oriented students that you decide to use a lecture format instead of experimentation?

Ms. Sunee: Actually, as I told you if there was enough time, they could succeed with this type of activity quite well. They are also

> interested if there is equipment but in the actual doing of the experiment, they tend to fool around instead.
>
> (Initial interview from November 12, 2008)

On the other hand, in the case of no availability of time or equipment, Ms.Sunee replaced the use of hands-on activities by utilizing demonstrations in front of the class or by using group demonstration for small numbers of students to observe closely. Most of demonstrations included using illustrations of models representing actual structures or processes in the Geology content. For example, Ms.Sunee used a boiled egg to represent the Earth's structure as a method to establish her students' understanding of the concept and for them to visualize better the layers of the Earth in a more concrete manner. When cut in half, each layer of the boiled egg from egg shell, egg white to egg yolk represented the different layers of the Earth as the crust, mantle, and core respectively. In addition, she asked the students to imagine other objects that are similar to an egg such as a watermelon that could be used to represent the different layers of the Earth. She described:

> …I explained the process that it *(the model)* occurred in the real world and its consequences. I tried to give the students a way to more concretely visualize the concept rather than just have them look in the textbook at illustrations (Initial interview from November 12, 2008)

The inclusion of hands-on activities explicitly shows the attempt on the part of Ms.Sunee to organize activities that better enable her students to understand the Geological content. She expressed a positive perception that student comprehension is better if they are involved directly in hands-on activities rather than just listening to her give them a lecture. <u>However, it is not certain if employing hands-on activities would encourage them to be mind on or not. Discussion during the activities is essential for students to construct their own knowledge and to integrate other science concepts that underlie the key notions being highlighted by doing the hands-on activity such as the types of forces and energy involved in the processes of plate movement or what causes the Earth's structure to be like the boiled egg.</u>

Task for searching information and performing presentations

As the concern on content coverage plays a vital role to drive the use of activities, searching for information as well as in-class presentations was another means to combine these two situations into one more effective one. A considerable amount of content can be covered in a small amount of time. This type of task was usually assigned to the students close to the end of the course. This type of task was not involved in the lesson plan at first and therefore the topics were uncertain. The topics studied varied in each semester. The students were responsible for searching for information, establishing reports and performing class presentations. Ms. Sunee pointed out the aims of this type of activity as:

> …Students selected one topic drawing from a box and were given time to study outside of class time and then to share the information by making a presention in front of the class. The presenters were to ask questions that would be answered by their audience the other students in the class. … This task did not originally occur in the lesson plans because it was a sudden solution of mine (Initial interview from November 12, 2008)

> … For example, regarding the content about Geological time periods which is taught in the last part of the semester, I assigned them to search for information and required this paper work for evaluation and also for them to make class presentations … It is uncertain which topics are going to be assigned to them. It depends on the time available and the situation. (Second interview from December 24, 2008)

It is possible that the task of searching information is really a double-edged sword because on one hand, it is an alternative way for the teacher to reconcile between a large amount of content to be covered in a small amount of time but on the other hand, it could make students appreciate that scientific knowledge presented in texts or internet databases without them being aware of the processes they used to acquire this knowledge as scientists do. This could put students in danger of not understanding the nature of science. Moreover, this method would not enhance efforts to integrate interrelated science content with Geology. As factual information in texts or other resources is generally represented in fragments so students could not be able to connect this knowledge to the Geological phenomena they are researching, but simply reading and then presenting the facts they found.

2. The Use of Teaching and Learning Materials

Reliance on text-based resources such as textbooks, maps and videos

As mentioned previously, Ms.Sunee's primary teaching method was by lecture. She most often used only the IPST student textbook and teacher's manual as her primary sources for planning and teaching her lessons. On occasion she used other sample textbooks from publishers for developing her reading sheets. She pointed out the reason she most often used the IPST textbook was because "the content in it covers all the learning outcomes listed in the science standards." (Initial interview from November 12, 2008)

When Ms.Sunee implemented some activities recommended in the text, she basically followed the procedures outlined in there on how to do the activities and raised discussion using the questions presented at the end of the activities. It was obvious that she was over-reliant on the textbook so she could be confident that she would not miss any key concepts that the students needed to know. This way she could also feel secure in her knowledge of the content and it would not go beyond what the standards expected.

Along with her transmitting of knowledge to the students based upon what is in the book, she usually showed short video clips regarding "Thai Geology" that were available from the Department of Mineral Resources and the Ministry of Natural Resources and Environment. These clips were a kind of short documentary that provided details about the structure of the Earth, important geological processes such as earthquakes and plate movement, or other difficult to observe processes or phenomena that are going on beneath the Earth and impossible to bring into classroom. Ms. Sunee felt that "it was very useful to include all content but unfortunately the students did not gain any thinking skills" (Initial interview from November 12, 2008). She also used illustrations or world maps to introduce concepts about the location of mountain ranges, earthquakes, and regions of great geological activity such as the convergence of two continental plates.

3. Assessment and Evaluation

Relying on traditional paper-and-pencil tests and exercises in the textbook with emphasis on the cognitive domain

Ms.Sunee commonly monitored her students' learning by using summative assessments. She used traditional pencil-and-paper tests to assess her students' learning at the end of each chapter, for mid-term and final exams. All of her exams were typically of a multiple-choice format concentrating mostly on the cognitive domain as it related to the Geology content, rather than on the scientific processes and the affective domain. Ms. Sunee kept a record of her students' progress by comparing their scores from their pre-tests at the start of a chapter and to their scores on the exams at the end of each chapter.

Besides exams, the students answered questions during the lesson or they read the content in the textbook and summarized it by answering the questions at the end of each chapter. They were required to submit their notebooks as another source for evaluation by Ms.Sunee. These types of tasks were generally assigned at the end of a chapter and usually in most of her lessons there was no formal assessment until the end of a chapter. She did observe their in class behavior looking at areas such as personal responsibility, interest, and curiosity when they were in class. When they made presentations, she observed them and evaluated their performances and their group collaboration. In terms of assessing process skills, this happened whenever the students did hands-on activities, but due to limitations of time and materials this did not happen very often. When they did do hands-on activities, she evaluated their ability to record data, write a report, and draw conclusions.

It can be viewed that Ms.Sunee adopted a summative format for her assessment methods and they most often occurred only at the end of chapters or semesters with formative assessment in the middle of chapters occurring very rarely. She used traditionally-based assessment and evaluation methods that were dominated by tests or practice exercises. These methods focused on assessing the subject content and did not assess the students' process skills or the affective domain.

4. Use of an Integrated Curriculum

Misunderstanding of integrated curriculum of the teacher

When asked about the use of integration in her teaching practices, Ms.Sunee was reluctant to explain her experiences because she was not sure what integration was. During a CAR group meeting, she explained her understanding of integration as:

> …Science is really not a single subject. It is very closely related to other subjects. For example, doing an experiment needs scientific process skills such as observation. Science is all about integration, because it is not a single subject. It (*integration*) needs the students' knowledge from studying a particular activity and then this knowledge needs to be added to the students' already existing knowledge. (First CAR group meeting from November 27, 2008)

Ms.Sunee's quote reveals her various understandings of integration as it relates to the scientific process skills that are used in all the science areas. She understands integration as the blending of 'students' existing knowledge' or 'prior knowledge' with new knowledge. Ms.Sunee stated that she was not quite sure what an integrated curriculum should look like and thus she could not say whether her teaching practices integrated or not, but she realized that science is an integral part of several other subjects. From her lesson plans and interviews she could not explicitly identify any of her teaching practices that involved integration of related science contents with Geological content.

In conclusion, in the first semester, Ms.Sunee relied heavily on a lectured-based pedagogical format as her main teaching practice because time was a key factor and she decided the most effective teaching methodology would be the lecture regardless of her beliefs governing the best ways to teach science, her educational background or her students' abilities. Being able to cover the most content in the most efficient way time wise was her first priority and she felt an obligation to fulfill the requirements laid out in the science standards. This was obvious by her use of printed materials, research tasks and presentations as her main sources to transmit the content to her students. Hands-on activities rarely occurred in her lessons, but she did do some demonstrations on a few occasions. Her assessment methods centered on the regurgitation of facts on exams and there was very little emphasis on assessing process skills. Concerning curriculum integration, Ms.Sunee held fast to her understanding that integration involved the interconnecting of existing knowledge with new knowledge but she could not give any examples of it occurring in her teaching practices.

Research Question II: How do Geology teachers change their teaching practices after participating in the collaborative action research group (CAR)?

To obtain insight into the understanding of Ms.Sunee's teaching practices when participating in the CAR group, the researcher carried out classroom observations of three single classes of one period and four double period classes, reviewed three teacher's lesson plans, conducted three post-class interviews, and gathered evidence from the CAR group meetings in which Ms.Sunee attended all. The themes that emerged from all the data collected are presented in the following five topics areas:

1. Teaching and Learning Processes

Positive disposition to include more activities to enhance students' participation, but with less student interaction, and teacher-dominated explanations

In the planning stage, Ms.Sunee took under consideration the idea of providing more hands-on activities in her lesson plans, instead of relying heavily on lectures as she did in the first semester. Ms. Sunee expressed her desire to change her teaching practices from simply transmitting knowledge facts to her students verbally in lectures to practices involving more hands-on activities as

> …I want to connect (*knowledge*) between what happened in the past and what exists today and the processes involved between those two huge steps. I have to find out the processes for students to best get this (*knowledge*). I try to find some activities everyday (*laughing*)….What the students are usually assigned to do is just to learn facts. For example, I assigned them to search for more information on a topic and to do a presentation. This was just about the facts. (Second interview from December 24, 2008)

An example of a hands-on activity from one of Ms. Sunee's lesson plans regarding the different types of plate movement, was the one in which she used models to demonstrate this concept. The models were used as analogies of the related Geological phenomena. This demonstration used the manipulation of every day materials to show how objects are changed as different kinds of forces and energy act upon them. This particular demonstration involved stretching a rubber band to show the accumulation of potential energy, a chopstick to represent direction forces pressing on it, sliding rectangular bricks to represent frictional forces along the plate movement, and a pack of different colored plastercine laid down in parallel pairs of different colors and then compressing these with a bar of wood on the opposite side of layers. Another example of an in class activity, was the use of a glass container filled with water to simulate convection currents that occur when the water is heated. The teacher set the apparatus in front of the class and used the visualizer to project it.

Another activity she developed was the cutting up of paper continents and then matching similar Geological trends in adjacent continents such as the Western coast of Africa and the Eastern coast of South America in order to find evidence that supports the concept of Pangaea. She also used the dehydration of plant leaves to simulate the process of fossilization.

Initially when the CAR group members discussed with Ms. Sunee her lesson plans, the group members discussed the issue of time constraints and they stated that she should not do simple generic everyday types of activities like burning candles because the students are familiar with this phenomena. This type of demonstration would not be necessary, but instead she should find activities that allow her students to think. Below is an example of the discussion and how Ms. Kanokpon played a central role in critiquing Ms. Sunee's ideas and how she shared activities from her own teaching experiences:

Researcher:	What do you think about Ms. Sunee's plan?
Ms. Kanokpon:	Personally, I think it a very long activity. She (Ms. Sunee) would not be able to cover all the content and would have to tutor. Instead she (Ms. Sunee) could briefly review an experiment the students did in the lower secondary level about phase change. … I think she (Ms. Sunee) could connect that demonstration to her (Ms. Sunee's) activity. I don't think the students should do an activity if they have done it before. Maybe just review the concept.
Researcher:	You may use a worksheet.
Ms. Kanokpon:	Or just ask them.
Researcher:	Yes, let the students answer these questions during the teaching and leaning time with no worksheet.
Ms. Sunee:	Like I said, I do not know if it is right. I am trying to think about how it would work in a real class situation. I want to try and do a more concrete activity. I also explain to them like you (*Ms. Kanokpon*) said in the class. I try to think about what I am going to do.

Ms. Kanokpon: Normally I ask questions regarding the students' basic knowledge. It's not usually this way.

(Second CAR group meeting from December 13, 2008)

In a real classroom context, Ms. Kanokpon pointed out the time issue of doing an activity in class. She suggested shifting from hands-on activities to discussions about situations that involve a phase change. The group members agreed with the suggestions and Ms. Sunee also welcomed any suggestions in which she could change her lesson plan that she would use the following week. She created a short quiz on phase changes in the context of every day life such as the melting of a candle. Ms. Sunee did continue to insist that some hands-on activities belonged in her lesson plans because she believed they would do a better job of encouraging her students' learning. In fact, she designed these activities for the students to play a central role by recording data, participating in class discussions, and drawing conclusions from the activities.

Ms. Sunee did struggle with the limitation of time in which to prepare lots of materials prior to her lessons involving hands-on activities and she sometimes had to forgo those lessons and use a demonstration with discussion instead. She stated:

> …If I did not have the time, I did demonstrations instead. The students were not allowed to do the activities themselves, but they could observe what happened in the process of the demonstration. It sometimes took lots of time to set up the apparatus …so, I used a demonstration instead. (Initial interview from January 23, 2009)

In the lesson plan, the students were asked to complete several pre-activity questions which asked about the objectives of the experiment, the variables of the experiment, or the analogy being used to represent the natural phenomena. The questions asked about the actual processes of which the analogies were to represent. For instance, in identifying the forces pressing down upon the layers of plastercine which is supposed to show the causes of continental drift, the students were to identify which layers of the Earth were represented by the different colors. This question allowed the students to discuss their opinions while at the same time made them focus on the concept and be more critical of their answers. However, when Ms. Sunee actually did this lesson in the classroom she did not follow her original plan and instead simple provided the students with the related facts while they observed her demonstration from their seats and they were given little opportunity to ask questions or discuss what she was doing. She did answer some of their questions.

She still explained the content and highlighted the key ideas for her students and the reason was because of time limitations. She felt too much pressure to cover all the content. She explained as:

> …One problem of choosing a teaching practice is time. There is often not enough time for me to teach using activities. That's what I'm always worried about. For example if I planned to teach an activity, I would have to hurry to let the students finish up in five minutes (Fourth CAR group meeting from January 24, 2009)

Instead she often used demonstrations by using models such as wooden blocks to simulate the Geological phenomena of fault lines or the process of convection currents in the magma found in the mantle by using boiling water. The use of activities was attempted as:

> …I designed activities in order to promote my students' understanding. Activities are the main character. If I use lectures, they are not able to participate. What I have done is to increase their participation in the lesson, to practice their process and thinking skills. I think these activities are the best way to encourage students to reach their goals of learning… It involves asking questions, finding and using equipment or technology for the students to interact with. This type of activity will allow them to use more of their thinking skills and their comprehension with improve (Initial interview from January 23, 2009)

When asked about her level of satisfaction regarding her actual teaching practices as compared to her designed ones, Ms. Sunee stated:

> …I am somewhat satisfied. As I told you, there are diverse factors like myself or the students as well as the setting up of equipment for various activities that affect how I teach. It also depends upon the students' participation in the lessons … (Initial interview from January 23, 2009)

From these excerpts, it can be seen that Ms.Sunee intended to shift her teaching practice from the teacher-centered lecture approach to include the more student-centered approach of using hands-on activities. Her attempts may not have been successful because of the factor of time limitations. Thus she utilized instead the teacher-lead demonstration-discussion approach.

Creating more time for eliciting students' prior knowledge

At a CAR group meeting Ms.Sunee discussed the issue of the students' prior knowledge and how to elicit it. The group suggested she use the idea of a diagnostic test a method that Ms.Sunee implemented. In the first semester, she relied on traditional paper and pencil tests, both pre-tests and post-tests, to monitor her students' understanding of the concepts she was teaching. These typically occurred at the beginning and end of a chapter. In the second semester she put effort into developing diagnostic tests that could be used as a tool to elicit her students' prior knowledge of a topic. These tests involved both open-ended and multiple choice questions, generally a few open-ended questions and about ten multiple choice. The tests were given to the students before she started a new topic and the students completed them in a short period of time (approximately 5-10 minutes). Ms.Sunee collected these tests and used them to obtain insight into what they already knew of the next topic's content. She was not able to finish her rubrics concerning her diagnostic tests as she ran out of time.

When asked about the feedback from the diagnostic tests, Ms.Sunee described that:

> …If I understand students' prior knowledge, I will be able to know how to better use activities that will relate the new knowledge in the topic with their prior knowledge. I can learn what the students really understand correctly and what misconceptions they possess … I ask them prior to the class, after finishing the class, and we discuss in order to draw a conclusion. I think that they respond (*to their knowledge*) quite well (Initial interview from January 23, 2009)

This quote illustrates that Ms.Sunee is aware that her philosophy regarding the elicitation of her students' prior knowledge has shifted from her original one in the first semester. At that time she utilized traditional pre-tests for as a baseline to compare her students' improvements after they post-tested but these pre-tests did not take into account what concepts the students already understood before beginning each topic.

Utilizing reading sheets and post-reading exercises, but still having explanations dominated by the teacher

Ms.Pimpon's discussion of her use of reading sheets with the CAR group inspired Ms.Sunee to develop reading sheets and post-reading exercises as an alternative activity for her students. The way she used reading sheets in the first semester was to summarize key concepts. In the second semester, the students were to read from printed materials that described content that went far beyond what was presented in the IPST textbook and any class discussions. These sheets also contained questions that would ask the students to utilize their knowledge.

Ms.Sunee utilized teacher-developed reading sheets and post-reading exercises in almost every class. Reading sheets were distributed to her students either at the beginning of the class or during the class. The students were assigned to study these sheets and answer the questions. From classroom observations, it was seen that

Ms.Sunee typically dominated the lesson by giving explanations on the essential content according to what was on the sheets, and she sometimes provided a very short time for the students to work by themselves.

Ms.Sunee's goal for using the reading and post-reading sheets was to aid her students' understanding by increasing their thinking skills and make them more interested. The students would be more responsible for their learning and be able to find things out for themselves. She described as:

> …Students could read and summarize the content on the sheets on their own. They have to be able to connect it to what they already know and use their thinking, analyzing and synthesizing skills … I give them questions for them to think about, to connect, and to answer. I ask them questions about experiments to motivate their curiosity or to build relationships between different kinds of knowledge (Second interview from January 7, 2009)

Ms.Sunee saw her reading activity as a student-directed activity, but from classroom observations by the researcher, it was obvious that this was really a teacher-lead activity because she clarified many key concepts for the students by her self. She explained many statements on the sheets and added many more details and all this took away from the students independently working on the task.

This is consistent with the feedback given to Ms.Sunee from the fourth CAR group meeting regarding her teaching practices. They observed that she should allow the students to ask more questions, interact more with each other, to participate in more open discussion and all this would improve their understanding of the Geological content. Ms.Sunee knew that she used traditional methods that were dependent upon explanations using the textbook and that her students often did not pay attention in class especially the non-science students. When she began to use the worksheets as post-reading exercises, they began to pay more attention in class and the number of students who handed in their homework completed increased. Her feedback to the situation went as follows:

> …Originally I assigned the students to read from the textbook. After I participated in the CAR group meetings, I developed questions for them to answer. The students seemed to need to know why they had to learn this subject matter. I created worksheets to be used as post-reading exercises. The students knew they had to finish these sheets on time. I used to teach until the end of the lesson and then test them, grading them only once. …In terms of the students' understanding, I think they now have a better understanding. Their thinking and discussion skills have improved. If I ask them the right questions they can make connections regarding what they have learned. (Fourth CAR group meeting from January 24, 2009)

This feedback by Ms.Sunee reveals the positive results of implementing reading activities as an alternative way to provide self-directed learning for her students rather than solely using teacher-led lectures. The important point for allowing self-directed learning was the development of the students' thinking skills which required them to construct their own understanding through reading and discussing with their teachers and classmates. At times she still played her "teacher role" making her the focus rather than allowing her students to discuss in small groups or as a whole class what they were reading.

2. The Use of Teaching and Learning Materials

In the second semester, Ms.Sunee continued to often use the IPST textbooks but not as much as she did in the first semester. She designed other teaching and learning materials that she had not utilized before.

Using real specimens to offer a direct experience by using hands-on activities

In the second semester, the students were allowed to observe the physical appearances of different types of volcanic rocks as well as study the reaction between them and acid. Ms.Sunee learned of this activity from the IPST textbook and from Ms. Pimpon's teaching practices. Ms.Sunee had to organize the types of rocks by herself since many of the samples she had were not properly organized. She explained the aim of using this activity as follows:

> …We did the activity to observe the differences between the different cooling down periods of the minerals in our rock samples to discover the origin of the rocks. The characteristics of the rock samples, such as hardness, endurance in their surroundings, corrosion and the shapes of their contained minerals were all examined. The students needed to examine real samples in order to best learn these concepts. (Third interview from January 28, 2009)

This activity was a good way to do difficult out of class fieldwork because the students could in fact bring in their own samples to study. This activity was a good way to interconnect the idea of real scientific study with direct student experience.

Reading sheets and post-reading exercises

According to suggestions from the CAR group, Ms.Sunee developed reading sheets and post-reading exercises in order to provide more information to her students. Content exhibited in the reading sheets was mainly adapted from the Geology textbooks and included text and images. Each set of reading sheets was not longer than seven pages so the students were able to complete them in class. Some examples of topics the reading sheets covered included the structure of the Earth in which each set of sheets included the properties of each layer, its physical appearance, chemical composition, relative density with respect to water, temperature and thickness. Ms. Sunee also developed reading sheets that discussed the tsunami topic and these included the relationship between tsunamis and their affects on landscape and ecosystems, their characteristics, and seismic wave behavior both p and s waves. These post reading exercises consisted mostly of short answer questions dealing with the content included on the sheets. She struggled with the constraints put on her by the school's policy regarding photo-copied sheets and as a result she was not able to print as many sheets as she requested.

3. Assessment and Evaluation

As stated earlier, Ms.Sunee's main assessment tools in the first semester were the paper-and-pencil test and having her students answer the questions at the end of the chapter. In the second semester she improved on these methods by adding other methods, but she still maintained her use of the paper-and-pencil test.

Using student worksheets and notebooks in an effort to examine the subject-centered domain

In the second semester student worksheets became the primary method of assessment used by Ms. Sunee. In a CAR group meeting, there occurred a discussion regarding the use of rubrics to evaluate student responses on these worksheets. The teachers were convinced by the group's discussions to transform their traditional method of scoring answers as either right or wrong and instead use a pre-determined rubric. In practice Ms. Sunee could not use rubrics because her worksheets contained questions that required responses that could only be judged as either right or wrong. She used this type of question because she had limited time in which to grade them and rubrics would have meant more time. Ms. Sunee pointed out the limitation of using rubrics as:

> …I did not use rubrics to evaluate my students' answers on their worksheets. I focused on whether the answers were correct or incorrect. Rubrics are much more sophisticated and require much more time to use. (Initial interview from January 23, 2009)

In the second semester, it was clear that Ms.Sunee assessed her students' understanding more often than she did in the first semester when she typically did it at the end of each chapter. In the second semester she distributed worksheets to the students in almost all of her lessons and they were responsible to complete the task within the class or sometimes she assigned them as take-home assignments. In the first semester Ms.Sunee also used the students' notebooks as a method of assessment, but in the second semester she did not use them as much. She still assigned the questions at the end of the chapter.

The main aspect of the assessment and evaluation in the second semester was the cognitive domain through the questions in the exercises. She rarely assessed the students' process skills and their affective domain. However, her main aspect of assessment and evaluation concentrated on the cognitive domain according to the questions she used. The assessment of process skills and the affective domain was rare because the teacher led the demonstrations and discussions rather than giving students an opportunity to perform hands-on activities and to work cooperatively in group. This was unexpected due to her inability to follow the lesson plan when implementing it in the real classroom because of time restrictions, facilities, and class size.

4. Using an Integrated Curriculum

Primary focus on intradisciplinary integration of other science content knowledge with Geology through demonstration and performing some experiments

An attempt to interconnect content from other areas of science to the Geology content happened when the researcher observed a class in which Ms.Sunee had her students do an experiment. Ms.Sunee expressed her reflections upon using experiments to integrate knowledge as follows:

> …Actually, understanding integration in science is shown much better by using experiments because the students can observe and touch materials directly. This leads to better understanding of integration of content than if they are lectured to. (Final interview from February 10, 2009)

An example of an activity that involved the integration of Physics concepts is the structure of the Earth activity. Ms. Sunee raised the issue regarding the changes that occur to a candle when it is burned. She did this in order to examine the students' basic knowledge of related science principles about thermal energy and the changes of state in matter with the concepts regarding the layers of the Earth's structure and their different states of matter, including a solid exterior, molten mantle, and solid core.

The activity she used was: 1) a candle placed in a dish being heated on a hot plate 2) dropping a piece of metal or any material which has a high density into the melted wax in the dish 3) removing the candle from the hot plate. The students and the teacher discussed the phase changes in each step. Step 1 a solid candle melts and becomes a liquid, then the metal added in step 2 sinks to the bottom of the liquid wax because of its high density, and step 3 when the candle is removed from the heat, it becomes a solid again, but before the piece of metal solidified. This activity shows the theory behind the origin of the Earth's layers. When the molten rocks began to cool down, the exterior of the Earth was already solidified, but the interior was still a hot liquid because the interior contained thermal energy that releases heat slowly. Ms. Sunee explained the aim of the integration in the lesson as:

> …Phase change happens in everyday life especially in water. Ice melts into a liquid, how can that happen? It is because the temperature inside and outside a refrigerator is different. This can be connected to the composition of the Earth. When matter changes phase, it releases heat. It reverses into a solid. Inside (*of the Earth*) is magma and when it reaches the surface it is lava. The temperatures at the surface are cooler so the lava releases heat and solidifies.… It's about how heat affects the bonding of atoms which results in phase changes. The inside and outside of the Earth is different and these differences can be related to temperature and thermal energy. (Second CAR group meeting from December 13, 2008)

Interestingly, there was collaboration among teachers when it came to sharing their teaching experiences regarding the concepts related to the Earth's structures. Ms. Kanokpon suggested the idea of characterizing the Earth's structure according to its chemical composition not only by using its physical properties as in Ms.Sunee's lesson plan. Chemically, the Earth can be divided into the crust, upper mantle, lower mantle, outer core, and inner core.

Researcher: What is the basic knowledge of the Earth's structure?

Ms. Sunee: Earth's structure is divided into three layers. The differences are their compositions and states of matter. The outside has been solidified. Beneath the surface of the Earth is molten rock. The core of the Earth is solid. Each layer of the Earth is different due to the attractive forces between atoms and the composition of the layer. Attractive forces differ due to thermal energy inside the Earth.

Researcher: That means you look at it in a physical way, don't you. Each layer has a different state. These are physical characteristics.

Ms. Sunee: Yes, the cause of the different layers is thermal energy…I am listening to everyone's comments, but I am not clear on the integration. I don't interpret it the same way I just find a way to help the students learn it.

Ms. Kanokpon: The structure of the Earth can be divided by its chemical composition. This means its study should require basic knowledge of chemistry in that each layer contains different types of elements. It relates to the origin of the Earth. When the Earth cooled down the heavy metals sank into the core. How would that happen and the less heavy metal like silicon stay outside? While all kinds of gases like carbon dioxide and hydrogen were emitted outside into the space. This guides the process of the Earth's structures. If students know the origin of the Earth, they know the concept of heavy metal going down into the core. We might compare this to stirring water to suspend some sediment. This produces some kinds of centripetal forces. It's about the origin of the Earth with regards to Chemistry. Which fundamental elements do

> students know? They should know some major elements because that is basic Chemistry. Personally, I usually teach chemical characteristics with the structure of the Earth along with the physical ones. The Earth can be divided into three layers based on chemical characteristics and five layers based on physical ones. I let students compare with each other. What is the criterion of the classification? Students can compare the elements of each layer. I use a graph to show the comparison of the elements in each layer. Students can tell that a layer contains plenty of silicon, just like the concept of the origin of the Earth. Silicon and aluminum are the second major components that appear on the graph. This is the way I teach.
>
> (Second CAR group meeting from December 13, 2008)

It is evident that the CAR group enhanced individual teachers' knowledge through discussion from their individual teaching experiences as a way to build communities of learning. In other words, Ms.Sunee learned another aspect of characterizing the Earth's structure from Ms.Kanokpon in the meeting which helped her to revise her plan by including the notion of chemical compositions and their density with the use of the periodic table.

In practice, Ms. Sunee raised discussion regarding the activity using a candle and this can be used to explain the Earth's structure and the students were given reading materials with a periodic table which illustrated information about the chemical compositions within each layer of the Earth. The students identified the density of each chemical element from the given periodic table. Ultimately, the class drew the conclusion that the denser elements in the core of the Earth lie beneath the lesser dense elements in the crust and the mantle.

Positive feedback on implementing integrated lessons, in terms of generating thinking skills, raising students' participation and being essential for all students unless having to be discarded because of time restraints.

When asked about feedback on using the integrated lesson, Ms.Sunee stated that integration plays a vital role in the teaching of science. Science is an integral part of various relevant principles from many different subjects. When teaching Geology, it must be recognized that it is not a science with its own specific knowledge, but that knowledge from many areas of science need to be integrated. Ms. Sunee pointed out this issue in the discourse with the researcher as bellow:

Researcher: Do you think that integration is essential for all students?

Ms.Sunee: Absolutely. We actually teach whatever to promote students to integrate *(knowledge)*. *(Science)* Knowledge is not fragmented into several layers. They should be given an opportunity to integrate … If there is more time, all students will be able to learn, but they may take varied periods of time to learn. …Teaching *(science)* knowledge is as integral part.

(Final interview from February 10, 2009)

When asked about the students' responses on activities based on integrated lessons, Ms. Sunee expressed:

> …I attempt to integrate knowledge to increase my students' understanding of what I am teaching them. I was pleasantly surprised for they actually understood better than I expected. The students learned many areas of knowledge not just solely those in Geology. It connected for the students the idea that science can never be just one solitary area, but that the knowledge from all fields is important and necessary for complete understanding of any area of science. (Final interview from February 10, 2009)

This quote implies that the intentions of implementing integrated lessons met with the teacher's expectations in some aspects because of the varied factors influencing the effectiveness of the integration. Ms.Sunee explained that:

> …When using integration, teachers have to prepare themselves in terms of the content knowledge they are going to teach and which subject the concepts are related to … They have to take more time and this means an increase in workload. It is also hard to cover all the content in the textbook. By using integration teachers have to bear with more workload, devote extra time for it, plan lessons and themselves. (Final interview from February 10, 2009)

Ms.Sunee stated that in order for teachers to integrate they will need more time to ensure they are well planned and thus they need to be dedicated to the idea of integration so they can attempt to input it into their lessons. Her teaching practices based on integrated lesson were also influenced by her limitation of time to plan whole new lessons and her need to have more time to complete the actual lesson plans in class. This ongoing problem of time constraints was a major factor in limiting the teacher's involvement in integration into the curriculum. This could possibly be a major obstacle to promoting curriculum integration into science teaching in accordance with the educational reforms.

In conclusion, in the second semester it was obvious that Ms.Sunee welcomed a more student- centered pedagogical format by providing the students with opportunities to learn from firsthand experiences. Her efforts helped the teacher to draw out the students' interests in their classroom activities and to establish a sense of responsibility for their learning. They also changed the class to a place where communication occurred more often between the students themselves and this allowed them to think and discuss in an effort to construct their own knowledge. Observing and making physical contact with hands-on materials and then following it with discussion were central components to Ms. Sunee's lessons. Content knowledge for integration was explicitly established by her collaborating and sharing with her colleagues in the CAR group meetings. Her integration involved teacher-lead demonstrations or discussion based upon her reading sheets. While the teacher's feedback on integration was quite positive, she still stated that integration was hindered by time constraints because the teaching practices that best implemented integration were also the ones that took the most class time and she may not be able to cover all the necessary content in the allotted time.

CHAPTER V

DISCUSSION OF COMMON FINDINGS FROM THE CROSS-CASE STUDIES

Chapter Five will address the analysis of all the evidence gathered from the three cross-case studies which were covered individually in chapters Four, Five and Six. Commonalities and differences were categorized into themes with discussion and supporting literature included in each theme. The cross-case studies discussion is organized according to the two major research questions and within these each are divided into the themes that emerged from each case.

<u>Research Question I: How do Geology teachers' actual teaching practices compare to the integrated curriculum's suggested teaching practices?</u>

Emphasis on national examinations or standardized tests puts pressure on Geology teachers' teaching practices

Throughout the study it was seen that in the three cases there was one instance, *Ms. Pimpon,* who addressed the issue regarding the emphasis put upon national examinations or standard tests as the focal point for making teaching decisions. Some of her activities involved the use of examples of previous national tests on her students' pre-tests, worksheets, or discussions in attempt to support her students' success on these types of examinations or tests. Her school put pressure on to ensure that the school's academic reputation be upheld when her students took examinations. She felt this enormous burden constantly and as well her students were under tremendous pressure to perform well on standardized tests, or entrance examinations which often only measures students' abilities to memorize random facts. *Ms. Pimpon,* feared her students might not have a complete knowledge base to do well on those types of tests. In the cases of *Ms. Kanokpon* and *Ms. Sunee* this issue was not a concern because in their situations maintaining a well known school academic reputation was not considered a priority. For them it was the expectation that the students would acquire all the content outlined in the national curriculum standards.

Both these issues however, made for a major gap to be bridged if the teachers were to adapt their teaching techniques to more favorable ones. Typically Thai parents believe that instruction should be based upon the idea that their children will before well on entrance exams, but this results in anxiety in the students (Jamon 1994). These entrance exams have for a very long time put emphasis on didactic learning and rote memorization rather than on inquiry-based learning (Longo, 2010). Intense competition to have great numbers of students do well or by parents just to have their own child do well has a great influence on teaching methods chosen by practitioners in all subject areas at all school levels. Examinations still have quite a strong influence on teachers' teaching practices (Sompongpon, 1991; Poochalerm, 2001) and this is despite the fact that the National Education Act B.E. 2542 (1999) and the National Science Curriculum Standards B.E. 2544 (IPST, 2002) calls for more emphasis on students' thinking processes, how to face various situations and the application of knowledge for solving problems. Unfortunately, teaching to the test or learning for the test is the actual teaching practice that many Geology or other science teachers use in reality. Teachers have to deal with the dilemma of whether to teach for the test or to teach in accordance with the educational reforms. A number of studies about the effects of national testing in schools have been done (Smith, 1991; Shepard, 1992; Pongsophon, 2006 and Chang, Chang and Yang, 2009). Shepard (1992) conducted classroom observations, meetings, interviewed teachers, students, administrators and other stakeholders. The findings showed that external testing affected the teachers' responsibility to avoid student failure and raised their anxiety to have students score well on these tests. This type of testing also reduced the amount of time available for instruction, or the teachers' abilities to organize the curriculum effectively and led teachers' to use instruction methods that would be support multiple choice type exams. The research by Chang, Chang and Yang (2009), studied the perceptions of secondary science teachers (grade 7-12) on the preferred teaching Goals of Earth Science Education (GESE) and their actual teaching practices in Taiwan. They conducted their research by using questionnaires distributed to over seven hundred secondary Earth science teachers, involved in teaching geology, astronomy, meteorology, and oceanography or marine science. The study showed that even though the science curriculum placed the goal of preparing students for the high school/college entrance examinations and/or preparing students for the next level (senior high school/college) tenth and twelfth in the ranking system, in actual practices in the schools, these goals were ranked second and seventh respectively. The study revealed that the emphasis on entrance examinations to prepare students for high school or college entrance examinations were ranked high in importance and significantly influenced the teachers' pedagogical priorities. It can be seen that there is a gap between the ideals of educational reform and the reality of the situation faced by teachers and students regarding examinations. In Thailand the national examination system has a huge affect upon high school students' futures as these grades are used for entrance requirements to attend colleges or universities. This may influence teachers' teaching practices to exclude hands-on activities and have students practice entrance exam questions as often as possible to succeed in any upcoming tests (Atagi, 2002). Standardized examinations which measure disciplinary knowledge could become the major force for teachers to avoid using integration in their classrooms (Berlin and White, 1991; Mason, 1996 cited in Czerniak *et al.*,1999).

Teacher awareness of students' prior knowledge is not a pedagogical consideration in the effort to enhance student understanding and traditional tests are utilized to grade student achievement

In all three study participants, eliciting students' prior knowledge occurred in a variety of ways, frequencies and intentions. In *Ms. Kanopon's* situation, there was no attempt to elicit students' prior knowledge during the lesson. She played a central role by reviewing the concepts the students had learned from the previous class and directly introduced new concepts to them. *Ms. Sunee* utilized multiple-choice pretests at the beginning of every single chapter but not in all her lessons. The scores from her tests were used as a baseline for comparing student achievement at the end of the chapter with multiple-choice post tests. This was a very traditional method in which to track the results of student improvement from the start and finish of a chapter. Discussions among the students about their prior knowledge did not happen anytime after the pretests in *Ms. Sunee's* situation. *Ms. Pimpon* expressed some concerns about her students' prior knowledge and she used pretests to motivate her students' awareness of their knowledge on their own. They had to do the same test at the end of every class to check whether they had improved upon their knowledge from that lesson. The results of these pretests were not part of the students' grading. As in *Ms. Sunee's* case, student responses in *Ms. Pimpon's* pretests were not included in any discussions or used in organizing classroom activities. Meinoratha (1997) conducted a study on the current teaching practices of Thai science teachers and she found that there were several methods of eliciting students' prior knowledge such as whole-class discussion, tests, worksheets, or questioning individual student. However, it was found to be evident that student's prior knowledge is not considered as the significant feature for motivating the construction of knowledge.

From a constructivist perspective, eliciting students' prior knowledge is an essential part of the process to know how to connect information to make scientific understandings mix with prior knowledge (Blake, 2004). The intention of eliciting prior knowledge is for teachers to know if students' understanding fits into one of the following categories; holding a sound understanding, an incomplete understanding, or an alternative understanding. If teachers identify students' existing knowledge base, they can plan activities that accommodate existing knowledge, new knowledge or assimilate an alternative concept to be a scientific concept as a method of conceptual change (Hewson and Hewson, 2003). In essence, Geology is the study of abstract knowledge where prior knowledge could persist in the form of everyday conceptions that could often be in contrast to the actual scientific concepts. To be taken into account, prior knowledge has to be organized with related concepts (Blake, 2004).

Teachers rely on didactic methods, mostly lecturing, or teacher-led discussions when students performed tasks, caused by teachers' beliefs about teaching science, resource-starved support and time limitations.

The teachers in all three cases dominated the transfer of knowledge to their students, but the amount of teacher-centeredness and the methods used differed from case to case. *Ms. Kanokpon* relied on 'talking' lecturing most often to introduce scientific knowledge to her students and had the students take notes in their notebooks by dictating word for word what they should write when she discussed key concepts. She explicitly described her strong belief that teaching and learning science using the lecture-based format was essential to science learning because it was the best to give key knowledge to her students whom were not able to summarize this knowledge independently. She had the students copy notes in their notebooks because she thought that the students were unable to learning anything by merely listening and it was beneficial for them to write the key concepts down. This would help increase their understanding and make a long-term record of important key concepts. In addition, she viewed the use of experiments in class as a less significant teaching method and thus *Ms. Kanokpon* felt compelled to continue her teacher-centered approaches to disseminating information to her students.

The growing body of literature regarding teachers' beliefs indicates that their beliefs have a significant influence on their decision making about what content to teach and how they will teach it (Hewson and Kerby, 1993; Abd-El-Khalick, Bell and Lederman, 1998; Brickhouse, 1989 cited in Eberle, 2008). Hashweh (1996) and Tsai (2002; 2007) and are convinced that teachers' beliefs regarding students' learning are considerably linked to teachers' actual teaching practices. In the other words, the selection and interpretation of the content by teachers for their teaching practices. If teachers think "teacher-centered approach" they use methods related to this philosophy to disseminate knowledge to their students and ignore efforts of educational reform to change them. In contrast teachers with a "student-centered approach" mindset to learning and teaching utilize different kinds of activities and provide opportunities for the students to construct knowledge for themselves. Therefore teachers' beliefs about science and the teaching of science needs to be crucially considered as to what content to teach, how to teach it most effectively, what ways to best use to help students make sense of the discipline as a whole (Eberle, 2008).

In the case of *Ms. Pimpon*, although her students typically studied content through worksheets and did participate in some experiments she frequently dominated in class discussions and dictated the conclusion of the activities rather than listening to her students' responses regarding what they had discovered. She felt she was forced to lead the discussions in order to cover key concepts especially those covered on former and future national examinations. She realized that her students had less opportunity to practice their communication skills or their scientific process skills like formulating hypothesizes or making conclusions. This actually fit the findings of many studies that concluded that *Ms. Pimpon's* teaching practices are quite because teachers of this kind focus on "content" or 'knowledge" because of pressure to raise their students' grades on standardized tests or national exams (Howes, Lim and Campos, 2009). The emphasis on memorizing facts and content leaves little time to focus on the scientific processes or other student-centered activities (Akkus, Gunel and Hand, 2007). Experienced teachers like *Ms. Pimpon* are more like disseminators of information rather than facilitators of learning and the facts they divulge usually come from government provided or recommended text-based resources (Adams and Krockover, 1997; Gess-Newsome 1999 cited in Eberle, 2008).

Unlike *Ms. Kanokpon* and *Ms. Sunee,* who had more recently taught Geology in the upper secondary levels, relied heavily on lecturing according to the content presented in the textbooks not due to her belief that this was the best teaching method, but because of time constraints and the lack of material resources for doing activities. The teaching of science has always been influenced by the accessibility to resources such as laboratory apparatus or the availability technological facilities (Spillane *et al.*, 2001). These are major factors that influence science teachers' in their decision about which pedagogical method to utilize in their classrooms. Even though *Ms. Sunee* recognized her major issues regarding her choice of teaching method she understood as well that her choice of teacher-centered didactic formats inhibited the growth of her students' process skills. This is consistent with the results of Lieberman (1995) in which he remarked that teachers' practices were not always in sync with what they believed and valued. However in *Ms. Sunee's* case there may be another reason for her choice of didactic lesson formats, she is beginning teacher when it comes to teaching Earth Sciences. She was faced with preparing lessons on content she did not feel confident teaching (Brickhouse, 1989 cited in Eberle, 2008).

In class-hands-on activities as a pedagogical tool are employed in a limited manner, and as a function of the teachers' beliefs, limited facilities, and the importance of time. Yet teachers play the central role when leading activities. As well no out of class field trips occur.

The major component of the student-centered pedagogical approach is a high level of student participation in hands-on activities. But in actual practice in the classroom, hands-on activities can often not take place for a variety of different reasons, teachers' beliefs regarding teaching methods, lack of materials or the limitation of time. The teachers in this study referred to the experiments laid out in the IPST textbooks which provided explanations of necessary materials, guidelines for procedures and suggestions for follow-up questions. The three teachers intended to do hands-on experiments with their students whenever there was sufficient time and materials available. *Ms. Pimpon* held firm to the practice of using hands-on activities and designed lessons in which the students manipulated concrete materials which provided her students with the opportunity to see 'first hand' simulated Geological processes and their results. However she did not follow up these good teaching practices because she did not engage her students in discussion regarding the activities and she did not allow them to come up with conclusions on their own. Instead in this area she took on the central role again because the activity took up too much class time and she needed to make up this time. It was obvious that *Ms. Pimpon* used traditional hands-on activities, or sometimes called "confirmation activity" (Llewellyn, 2002). *Ms. Pimpon* provided her students with lab sheets that outlined the materials, procedures and questions to follow in a recipe type manner to ensure the students came up with the correct results. Although the students had a great opportunity to perform a hands-on activity as a manipulative means of learning, it tended to be more of a teacher-initiated inquiry activity, rather than a student-initiated inquiry activity in which the student should have a more active role and be able to raise their own questions, formulate their own procedures, and investigate their own results. "The activities were served like a cookbook recipe simply to verify or confirm already stated knowledge and show how a set of scientific principles or truths apply to life." (Llewellyn, 2002: 30).

In *Ms. Sunee's* situation it was the lack of facilities and limitations on tie that kept her from using hands-on activities with her students. Instead she used teacher-led demonstrations in which the students observed the procedures and results. She was in fact aware that her lessons were not the most effective for facilitating student learning and she knew that using hands-on activities would have been more beneficial. In the case of *Ms. Kanokpon*, she believed that using hands-on activities was not appropriate to use for the Geology content because it was just too time consuming, difficult to do, and the lack of materials and chemical substances. She preferred to use the much quicker teacher-led demonstration approach and if time was even more limited she just gave direct explanations of experiments to the students. Thus there was a lack of hands-on activities occurring in all three cases, but there were some different reasons as to why.

Studies regarding the teaching practices of Geology teachers have reported that when curriculum changes are made to include more hands-on activities, teachers in many countries avoid the use of these recommended activities. (King, 2001; 2003) An important feature of integrated curriculums is the engagement of students in hands-on activities in order to provide the students with experiences in order to link a variety of relevant knowledge. In fact, doing experiments plays a central role in the teaching and learning of science in terms of improving students' scientific process skills such as observing, analyzing and interpreting data, being able to discuss in groups, building a scientific mind, as well as using scientific inquiry to solve problem all of which is mentioned in sub-strand 8 of the National Science Curriculum Standards (IPST, 2002). However, the study of Nakthong, Anuntasethakul and Yutakom (2007) found that Thai students in the upper secondary levels lacked some scientific process skills such as calculating, proposing hypothesizes, and drawing conclusion. The researchers suggested teachers should not focus on memorizing content, but use more hands-on and minds-on activities when teaching science. Germann and Aram (1996) conducted a study of 364 science students in grade seven regarding their ability to perform the science processes, including recording and analyzing data, drawing conclusions, and providing evidence. The study found that over ninety percent of the participants did not pay attention to the hypothesis when drawing conclusions. Demonstration could be used to invite further inquiry-based questions if teachers would not use it just to demonstrate a particular phenomenon without good discussion or questioning techniques. Much educational literature suggests that useful demonstrations can motivate students' attention, questions, curiosity and imagination if the demonstrations relate to discrepant events (Llewellyn, 2002; Wright, n.d). The main aim of a demonstration is to attract student attention and interest, but often the teacher takes too much control and the students are simply passive participants. If a teacher uses a demonstration they should ensure that it is supporting the development of the students' process skills and provides them with the opportunity to raise questions or explanations for what is happening.

The problem with Geological phenomena is that it occurs in natural settings of which a classroom is not and therefore providing the students with opportunities for field trips would better ensure their understanding of this phenomenon. Students could observe the impacts of this same phenomenon upon the Earth's surfaces or the impact it has on living things. None of the three teachers in the case studies took their students on a Geological related field trip even too a museum. The major reason for this was the lack of support from the school for this type of activity. Too many issues regarding student safety, school budgets and time availability prevented field trips from happening. Thus the students in these teachers' classes never had the opportunity to learn about Geology phenomenon in a natural setting. This is consistent with reports that the majority of students studying Geology never learn about it natural settings and this is especially true of students in urban areas (King, 2001; 2003; Dodick and Orion, 2003; Hanpipat and Roadrangka, in press).

Many researchers point out the importance of fieldwork in teaching geology (Dodick and Orion, 2003; King, 2008). As well Geology is a distinctive field of science that requires thinking and investigation skills. One of five attributes of geosciences education reported by King (2008) is geosciences fieldwork. Students must acquire multiple skills for understanding filed context. More importantly, experimentation and simulation in the laboratory should not be a substitute for evidence gathered in the field (Dodick and Orion, 2003). The field offers important educational opportunities that include:

> …1) the study of processes and their products not available in the classroom, with their variety of scales, dimension and complexity 2) the application of outdoor investigational skills and techniques that cannot be used in the classroom 3) a wide range of new problem-solving and investigational possibilities: the evaluation of varieties of evidence, the interpretation of changes through space and time; the detective work involved in retrodiction, the evaluation of resources and the assessment of the environment; and 4) the potential development of new interests, attitudes and values relating to the outdoor world (King, 2008: 202).

The National Education Act B.E. 2542 (1999) states that in order to promote the idea of lifelong learning it recommends the use of a variety of out of school locations such as museums, zoological gardens, public parks, botanical gardens, and other sources of learning. Education in other western countries, particularly in the United States of America or Canada, has increasingly concentrated on out-of-school learning as Informal Science. The National Association of Research in Science Teaching (NARST) has approved the idea that students should be able to learn from a variety of learning resources (Dierking *et al.*, 2003). Anderson *et al.* (2002) asserted that learning in museums could maximize students' interpreting skills via their experiences, cultures, beliefs and values. In the view of integration, fieldwork is so called 'integration-in-action' which enhances students in bringing and applying knowledge across varied disciplines in real world. It allows for more understanding of knowledge in daily life (Minnis and John-Steiner, 2005).

The use of searching information from out-of-class resources as an alternative way to transfer knowledge from text-based resources to students

Ms. Kanokpon argued that having students search for information, using multimedia resources, and making models was more suitable to the Geology content than doing experiments. This statement supported *Ms. Kanokpon*'s view regarding the use of experiments in her teaching practices. She assigned different topics to each group giving them a week to prepare their presentations. *Ms. Pimpon* occasionally assigned her students to work in groups to make a presentation on Geological phenomena. But in her case, unfortunately due to time constraints her students' work did not seem to contribute to the whole class. *Ms. Sunee* utilized her students' presentations as a last resort when she was squeezed for time and could not meet her expectations in her original lesson plans.

All of the teachers in the study believed that "text-based" science allowed their students to access scientific facts and content that they could not cover in the classroom. This "text-based" resource included the students' textbooks as well as any internet sources they accessed in doing their research. Although, textbook or internet-based resources may support students' learning by themselves, this approach is really not better than the use of lecture done by the teacher. Teachers want to avoid using the lecture format and use the idea of having students search for information independently as an alternative approach, but they forget that students might misunderstand the scientific knowledge or content they are finding because of poor resources, especially with some undependable websites (Howes *et al.*, 2009). This type of activity can be a double edged sword, on the positive side it allows for the covering of a large amount of content in a short period of time outside of class time, but on the negative side, the students may not be learning correct knowledge. It may end up being a "dogma carved in stone" (Ford, 2006). Wrong information may be difficult to "unlearn" later and their experiences might hinder the inquiry process and any understanding the students may have regarding experiences similar to what scientists actually do. Teachers should perhaps use "text-based resources" simply as a tool to support inquiry-science teaching practices.

The use of teaching and learning materials that highly emphasize the cognitive domain and factual aspects with little emphasis on manipulative materials

All three teachers' teaching practice utilized diverse types of teaching and learning materials which included real specimens, worksheets, models, or videos in spite of having to face shortages of materials and lack of facilities. Worksheets were the most commonly used teaching material. Some were developed entirely by the teachers or they were adapted from other resources and they were used differently by each teacher. *Ms. Pimpon* emphasized worksheets in every lesson, while *Ms.*

Kanokpon often used worksheets as a student homework assignment after she was finished a chapter so they could review what they had learned. In *Ms. Sunee*'s classroom, she used her worksheets to summarize the content for the students when she ran out of teaching time. All three teachers used worksheets as an essential resource in covering all the necessary content.

On some occasions in her classroom, *Ms. Kanokpon* used three-dimensional models of volcanoes or tsunamis that had been constructed by previous students. She had her students create these types of models because when she was first began to teach Geology there was a shortage of resources in its content area so she gave her students the task of creating models and she kept them each year so she could use them in future lessons. *Ms. Kanokpon* sometimes used videos to support her students' learning, showing them videos that highlighted the characteristics of Geological phenomenon. *Ms. Pimpon* was the only teacher who utilized real specimens that she got from her experiences attending workshops, courses and field trips. She also asked students and parents to donate any specimens they might have. It was like doing a "field trip" in the classroom without have to leave the school, learning about Geological phenomenon in a natural setting as best as possible.

These findings fit into the study of Roadrangka (2008) in which she indicated that most Thai science teaches used a variety of teaching and learning materials in order to improve their students' thinking, learning and increase their interest levels in science. But because the content related to Geology is distinctly abstract such as the mechanisms that underlie plate tectonic phenomena it is very difficult to be able to observe this type of phenomena naturally in the classroom. As a result teachers try to make the content less abstract and more concrete by using teaching and learning resources such as videos, models, experiments that represent the content. Aubusson (2002) provided one of the most widely known resources, citing the work of Gentner (1983) the use of concrete models as analogies for making abstract knowledge regarding unfamiliar content more familiar or concrete. Each teacher in this study relied on various kinds of modeling which included diagrams like the ones that showed the Earth's structures used by *Ms. Sunee*. The physical sliding wooden frame model used by *Ms. Pimpon* to represent drifting of plates along fault lines and the three dimensional models of the volcanic types used by *Ms. Kanokpon*. Modeling is necessary to enhance students' spatial abilities (three-dimensional thinking) which are crucial to understanding geosciences (King, 2008). Nevertheless, employing these types of analogies has both strengths and weaknesses in representing abstract content to make it more concrete for the learner. In fact, concrete models sometimes are not totally true representations regarding actual geological structures occurring in natural settings and this might lead to confusion on the part of the students' correct understanding (Kali, Orion and Mazor., 1997). To be used effectively, modeling activities should be used along with discussion and the teacher should provide guidance rather than just show or demonstrate the model and disseminate information while doing so (Aubusson, Harrison and Ritchie, 2006).

Assessment and evaluation show prevalent emphasis on the cognitive domain, and there is little opportunity to monitor other domains

All three teachers used both formative and summative assessment. For summative assessment, all of them used paper-pencil tests in for the mid-term and final examinations. In the case of *Ms. Sunee* she solely used traditional pretest and post test exams for assessing her students' progress at the beginning and end of lessons. *Ms. Pimpon* and *Ms. Kanokpon* used student worksheets that consisted mainly of short answer questions. *Ms. Pimpon* usually assessed her students in every single lesson using worksheets while *Ms. Kanokpon* used worksheets only at the end of the chapter. *Ms. Kanokpon* concentrated more on her students' notebooks during the week to monitor her students' attention skills and personal responsibilities in class. In all three cases, the teachers' assessment methods concentrated on the cognitive domain and put very little emphasis on other domains such as the psychomotor or affective. *Ms. Kanokpon* utilized different types of assessments such as in-class observation of her students' performing group presentations on assigned topics they researched outside of class time. Additionally, the students were permitted to assess their peers' presentations using teacher-developed criteria. *Ms. Sunee* on a few occasions observed her students making presentations in groups when she quickly assigned them topics because she ran out of teaching time.

The methods of assessment and evaluation varied widely in all three teachers' classrooms and included student worksheets, student presentations, student group work, or tests. Teachers attempted to assess and evaluate all three major domains cognitive, psychomotor, and affective even though their methods most often focused on the cognitive domain. This contradicts with the study of Meinoratha (1997) and Roadrangka (2008) which found that the majority of Thai science teachers had a tendency to use assessments and evaluations in correspondence with the National Education Act B.E. 2542 (1999) which was obviously high when considering students' improvement, behaviors, learning behavior, attention in classroom activities, and taking exams altogether.

Generally assessment of the cognitive domain is emphasized over the science processes and affective domain. Multiple-choice exams are the most useful in measuring students' abilities to recall facts, comprehension, application, or analysis. It has the advantage of covering a lot of content effectively and can be easily scored. Nevertheless, it also has limitations in that students do not have the opportunity to provide specific understanding that is not contained within the exams. These findings aligned with the study of Chang, Chang and Yang (2009) who studied preferred and actual teaching practices of Earth science concepts. They discussed the difference between the two domains. Teachers preferred teaching goals concentrated on the attitude domain as an important priority, but their actual teaching goals had a higher emphasis on the knowledge domain. "Students acquire basic Earth science concepts" and less emphasis on attitude toward Earth science "students appreciate and value the beauty of nature".

Teachers usually integrate more Geological content with other disciplines, but less of it within science disciplines. A possible reason is the lack of thorough Earth science knowledge and understanding of integration on the part of the teachers

Ms. Pimpon saw integration occurring across other disciplines such as English language; geography and technology when she used crossword activities or had her students make crystal shaped lamps. Her integration of other science related content was rare because she felt inadequate in her understanding of the knowledge from other sciences to interconnect it with Geological content. Likewise *Ms. Kanokpon* was also reluctant to discuss related science content outside of Geology because she was unsure of her knowledge. Both these teachers had a weak background in Geology and it made them reluctant to move beyond the content that they understood. In regards to educational background, Hanpipat and Roadrangka (in press) surveyed teachers' education backgrounds, current teaching practices and problems in teaching Geology after almost ten years after the implementation of the recent version of the National Science Curriculum Standards in Thailand. Questionnaires were administrated to teachers in 35 public secondary schools in the School District Service Area, Office 2 in Bangkok. The study's results indicated that the majority of Geology teachers had backgrounds from a Faculty of Education majoring in general sciences or the teaching of science but did not have a major in the area of Geology. Forty-six percent of secondary Geology teachers graduated with a Bachelor's degree of Education majoring in general science teaching and seventeen percent had completed a Master's degree of Education in teaching science but none of the teachers had a background in Geology.

When considering the teaching situation in Thailand Silpabanlaeng (2005) and Silpabanlaeng *et al.* (2006) showed that there was a discrepancy between the areas of expertise needed and the actual graduates. In particular regarding the graduates from the many Faculties of Education and Teacher Colleges as these institutes only offered four different fields of science in the area of school curricula, Physics, Chemistry, Biology, and General science. The new science curriculum now included content in the Earth Sciences but there were qualified graduates available to teach it. The Institute for the Promotion of Teaching Science and Technology (IPST) was supporting students learning in hopes that they would chose a future career as science teachers by providing funding in the areas of Mathematics, Physics, Chemistry, Biology, and Computer science, but not in Earth Sciences. Many new or retrained teachers were necessary to tackle this area of content. As well a survey of the science teachers already teaching Geology (namely geosciences) done in the late 1990s (King, 2001) indicated that these teachers possessed poor levels of knowledge in the content of Earth Sciences and generally relied on science textbooks and colleagues to support them, but not fieldwork. They were convinced that

> …their background knowledge of Earth science from their own education was generally poor…they reported that their main resources of Earth science knowledge and understanding were the broad scoped science textbooks (with their small and variable Earth science content) and science colleagues (who often had a poor background in Earth sciences too). The low levels of practical, investigational and fieldwork recorded may be a reflection of their poor Earth sciences background. Most teachers indicated that they needed more support in this area. (p. 636).

Ms. Sunee viewed integration as a combination of basic knowledge of from previous classes with new knowledge gained in the most recent lesson. This perception was not consistent with the educational definition of integration. This made her uncomfortable discussing her integration practices. Her teaching of Geological content followed the content as it was outlined in the textbook and this content was often very basic and did not show how it related to the content of other areas of science. There is therefore an urgent need to support teacher practitioners understanding of the definition of integration in order for educational reform to be put into practice.

Overall, teachers usually utilized an interdisciplinary integrated curriculum while intra-disciplinary integrated curricula were not often used when teaching Geology content. Much research has indicated that most teachers are not comfortable using an integrated curriculum (McComas and Wang, 1998; Meier *et al.*, 1999). Teachers especially those in the upper secondary levels where the science disciplines are distinctly separated were not confident to attempt field trips with their students. As a result these teachers tended to not use integration among the various science disciplines even in spite of the fact that Earth sciences depends upon the content of many other science disciplines to understand its concepts. The students studying the Geological content conceptions tended to be uneven in relation to other disciplines' role in Geological content and thus created a barrier for their complete understanding of Earth functions as a system. Teachers should reinforce the understanding of Earth science concepts by making them relevant to the other sciences involved rather than teach them as isolated concepts (Blake, 2005). This cannot be achieved unless the teachers doing the teaching feel confident in their knowledge base and therefore there is a need to provide teachers with quality professional development in this area and to promote their attendance in courses and workshops. However, this still doesn't ensure that these newly trained teachers will teach the students effectively (Walker and Cheong, 1996).

Individual teachers in this study, displayed unique methods of integrating other related content with Geological content. In *Ms. Kanokpon*'s case she questioned the class one whole group when she introduced a new concept. For instance, she questioned all the students about the relationship between temperature and the speed of lava eruptions and how this affected the formation of different types of volcanoes. Her questions were typically of the yes/no type of they involved the choosing between two provided responses (high temperature or low temperature, high speed or low speed). Both types of questions only required low level thinking skills and as a result her students were not using their critical thinking skills to relate this Geological content they were learning with the content in other science disciplines. In *Ms. Pimpon*'s case, her worksheets provided the main source for integration. In the crosswords for example she integrated English into the study of Geological vocabulary. She also intended these activities to be used to motivate her students making the learning of new content almost like a game. She did not however make the connection between the two disciplines, English Language and Geology because she didn't provide opportunity for discussion on how they were interconnected.

On the whole though, the three participants attempted to interconnect other content into their Geological content, but there were no attempts to encourage integration in more effective ways. It was almost like it just happened accidentally without any conscious thought on the part of the teachers. This was probably due to their background in other areas of science as well as Geology and they did not feel adequate to include other relevant principles in their teaching practices (Singletary and Miller, 2009). Green (1991) was convinced that in-service teachers probably lacked experience in teaching an integrated curriculum. Their situation was not unlike those of pre-service teachers who had any experience in using an integrated curriculum in teacher's college or university. This situation is also feed by the limitation of the traditional method of keeping science content specific to a particular discipline while studying in university, college or even in upper secondary school. It is difficult to establish an atmosphere of integration when the traditional method to teach science content dictates it placed under the heading of a specific area of science such as Biology, Chemistry, Physics, etc (Firth, 1998 and Max-Neef 2005 cited in Saito *et al.* 2009; Singletary and Miller, 2009). In order for more integration across science disciplines to occur it necessary to apply the related principals of integration when implementing any science course including Earth Sciences (Dal, 2009).

Teachers' selection of content for integration is dependent upon their students' abilities

In Thailand students in the secondary level are offered a variety of programs based upon their interests and abilities. Typically, science-oriented and non science-oriented programs are two examples of options offered and each has significant syllabus differentiations again based upon the interests, abilities and personal responsibilities of the students in each track. All upper secondary level students whether they be science or non-science have to study Geology thus the teachers of the subject have to consider the students' abilities when designing lessons appropriate to the different groups of students. *Ms. Pimpon* figured it out that non-science oriented students were unable to understand the difficult concept regarding the relationship between radioactivity and rock dating so she decided to integrate this chemistry content into her Geology content only in the lessons she planned for the science-oriented students who were seemed to be able to understand its functions, characteristics and benefits. *Ms. Pimpon* considered the abilities of her students when planning lessons on topics that were considered quite abstract and difficult. *Ms. Kanokpon* also considered her students' abilities when planning her lessons by considering the sophistication of the content and whether or not it was suitable for the students in her classes. Sometimes she only changed the type of questions she asked of the classes. As teachers come to know their classes better they can choose or even create the proper activities that will lead to their better understanding of the content or even pique their interests. They need to ensure that the content is challenging for all students and thus not too easy for the bright ones and yet not to difficult for the ones who might have more difficulties. But they all need to learn basic concepts that are required by the curriculum (Srisaart, 1994). This must occur even if the IPST textbook includes content that most teachers find too complicated for the non-science orientated students (IPST, 2005b).

Research Question II: How do Geology teachers change their teaching practices after participating in the collaborative action research group (CAR)?

CAR group meetings to support teacher collaboration in developing an integrated curriculum both in subject integration and instructional integration yet barriers to effect change in teachers' teaching practices corresponding to the CAR group meetings still persisted

Evidence from CAR group meetings and follow-up interviews explicitly addressed the establishment of a learning community among teachers as a result of the sharing of experiences, criticizing significant drawbacks, and the suggesting of interesting ideas of teaching. The meetings became a place where the teachers could broaden their views, learn new ideas, strengthen and improve their knowledge of the content they were teaching and take away with them some new pedagogical strategies to improve their teaching and their students' learning. *Ms. Sunee* found support for her ideas concerning subject integration. When she was teaching the structure of the Earth she based her lessons only on the physical characteristics of the layers to show their differences. From her participation in the CAR group meetings she learned that chemical composition can also be used to explain the structures of the Earth and she added this to her lessons. *Ms. Pimpon* took away the suggestion that she strengthen her use of reading materials and post-reading exercises to enhance her students' abilities to interconnect the fundamental concepts with Geology. *Ms. Kanokpon* who joined the group late, enthusiastically contributed her experiences and shared comments with the other teachers. She herself was given support to encourage more two-way communication from students' in her discussions in class rather than them always simply being quiet and listening to her talk.

Educational literature supports this idea that it is important for teachers to be involved in collaboration in meaningful professional development programs that helps teachers to improve their teaching practices (Lytle and Fecho, 1991; Little, 1993; Lieberman, 1995; Abell, 2000; Spillane *et al.*, 2001; Guskey, 2003; Jang, 2006). Spillane *et al.* (2001) elaborates that this is a crucial resources needed for change to happen in teaching practices. Not only do knowledge and expertise themselves lead to change but 'human resources' also play an essential role in improving teaching practices. Human resources does not just mean an individual teacher's knowledge, but it involves "social resources" the pooling of teachers gathered together building trust and communication. Efforts should be made by supporters of education to build communities of teachers and their colleagues to encourage communication and the sharing of experiences. "The group rather than the individual is the more appropriate unit when investigating the resources for leading instructional change" (Spillane *et al.*, 2001: 936)

Although the call for building a collegial environment in workplaces has been identified as a key aspect in teachers' professional growth most teachers operate in isolation. Jang (2006) remarked that there are three major factors that reduced collaboration among professional teachers; 1) opportunities of collaboration among teachers are limited and tend to be more informal and infrequent in communication 2) school structure or block scheduling emphasizes teacher autonomy to teach students independently without assistance from others and does not support a collaborative environment for teachers to plan, learn, or observe each other (Guskey, 2003) 3) a lot of time is needed for teachers to work together to plan, teach and evaluate and create relationships that lend themselves to the trust that is needed for collaboration. Collaboration needs a lot effort on the part of the teachers to put it into practice (Lytle and Fecho, 1991). There attempts may not work out each time it is tried because there are many factors working against it.

The changes that occurred in the teaching practices of the three participating teachers after they attended the CAR group meetings were varied. These changes happened in some aspects according to the suggestions from the CAR group. However some of their more traditional teaching practices were maintained. *Ms. Kanokpon* for example still used the lecture-based format directly explaining concepts to her students as they wrote down her statements. She did attempt to use more experiments to demonstrate Geological processes such as convection currents or seismic waves even though she personally did not believe this was the best way to teach Geology. As well the CAR group led her to change the way she organized her lesson plans by including the idea of eliciting students' prior knowledge by posing questions that could be discussed by the whole class.

In *Ms. Pimpon's* case, she still put emphasis on providing her students with worksheets as her main in class activity. Her teaching style did not show dramatic change after the CAR group meetings, but the concepts involved were much more complicated than before and they revealed integration. To enhance her students' abilities to interconnect ideas, she created reading sheets that covered the main themes, but she divided these further into related sub-topics. Students were responsible to study the sheets thoroughly and then respond in a post-reading handout that emphasized the connections. She also included some hands-on activities in which the students were allowed manipulate the materials themselves. She did not include any activities of this type in the first semester. Her students became more interested in what they were learning, their voices were heard more often in constructive ways and their scientific process skills were being challenged especially in the area of recording and interpreting data through discussion.

Ms. Sunee showed remarkable shifts in her teaching practices from relying heavily on textbooks via lectures to organizing a wide variety of activities such as implementing reading materials, demonstrations of experimentation in efforts to engage her students more actively. She was still concerned that all the students needed to observe a particular phenomenon, but in the past she played the central role in disseminating the knowledge regarding this phenomenon. After her participation in the CAR group meetings, she allowed and facilitated more student discussion without regard to time limitations and she learned to integrate science principles into her teaching practices.

The CAR group meetings were a place for the teachers to share and learn useful content knowledge, values, experiences, and suggestions from each other, however, not all of their original teacher practices or beliefs changed from their participation in the group sessions. *Ms. Kanokpon's* teaching practice is strongly influenced by belief-driven discomfort and pedagogical insecurities and these impaired her from shifting all her teaching practices (Frykholm, 2004). One particular discomfort that many teachers possess is the belief that students learn best and that science should be taught in line with the constructivist approach. *Ms. Kanokpon* had a difficult time accepting the idea of an integrated lesson because it took lot of effort to design activities and because it was not consistent with her rigorous beliefs about the nature of geology. A study of long-term professional development in Israel gathered from questionnaires and interviews regarding teachers' perceptions and their actual teaching practices (Orion and Ault, 2007:679) concluded that:

> …In addition to teachers' reluctance to implement new teaching methods and incorporate new scientific topics, the interviews uncovered additional factors that prevented them from genuinely implementing reform. They felt, in general, apprehension toward change and that professional training institutes did not provide them with the practical tools needed to overcome their apprehension. Teachers believed that school administrators failed to provide them with the resources necessary for reform, such as laboratory equipment, smaller class sizes in the laboratory, computers and access to an outdoor learning environment…

Remarkably, there is a contradiction of behind what professional development for teachers actually concentrates on to initiate when what teachers actually need to change is more tools, like materials, facilities or even smaller class sizes.

Teachers attempted to provide a supportive environment in a constructivist-based learning environment to support integration but several barriers to the efforts still remained.

Traditionally, Thai education has concentrated on rote-learning studies over students' thinking, cognitive skills over the science processes and affective development and individual learning over cooperative learning. It has been crucially criticized for long time that these features have never really served the quality of students' learning and do not meet the call for educational reform. Reduction of these contradictions could help to establish a more supportive environment that would be more consistent with a student-centered emphasis when implementing integrated lessons in the classroom. A supportive atmosphere for student collaboration in groups is essential to integrate learning (Braunger and Hart-Landsberg, 1994). Transmission of knowledge and fragmented teaching practices cannot enhance students' deeper understandings of Geology and non-constructive integration cannot help them make connections between related concepts. A classroom should not just be place where subject content is deployed to the students without them directly involved in their learning. This should be done through self-direction, participation in discussions, and discovering knowledge from exploration in a hands-on fashion. As teachers learn to recognize the importance of integration within the Geology content they will begin to create more effective learning environments and move away from the typical traditional lecture based classroom experience. All the teachers in this research study, made more effort to actively engage their students in some portion of the lesson. They created lessons that incorporated a number of more student-centered activities like making oral presentations and investigations. These teachers moved away from the lecture format. *Ms. Kanokpon* used discussion to elicit prior student knowledge so she could better plan her lessons based upon what they already knew. She utilized demonstrations of experiments to discuss with the class the topic of convection currents, engaging students by giving then a chance to share their opinions on the topic. *Ms. Sunee* put her main emphasis on student involvement in hands-on activities such as classifying rocks and teacher-led demonstrations for them to observe Geological processes through various kinds of models. She stated that she was able to keep the students' attention by using these types of teaching practices and it provided her with strong feedback to continue to do so. The teachers also shared positive feedback that these types of activities motivated their students' interest, encouraged the development of their science process skills and their understanding of the content knowledge being presented in class when they were involved in these activities. This fits with the findings of earlier research that suggests the importance of providing a supportive atmosphere where students are central in the environment is key to students' learning and to capturing their interest (Chang and Taipei 2002; Lee and Fortner, 2003 cited in King, 2008). Chang and Taipei (2002) concluded the provision of constructivist learning environment in Earth science teaching practice. Not only problem solving skills did become increasingly distinct, but also science process skills such as observation and hypothesis skills was infused throughout all Earth science curricula. While Lee and Fortner (2003) reported that the use of a constructivist-based teaching in the Earth system curriculum, involving hands-on activities, authentic activity-based learning, cooperative learning, project-based learning, and field trips increased level of students' understandings.

Something interesting happened as the teachers shifted their teaching styles from teacher-centered one to more student-centered ones. The teachers found that the students were more motivated to pay more attention in class, but this did not mean it always went smoothly. In *Ms. Pimpon's* case she was concerned because her students had difficulty doing these new hands-on activities and still needed direction from her to be able to be successful. *Ms. Kanokpon* and *Ms. Sunee* in their attempts to engage the students in classroom discussion struggled with the few numbers of students who raised their hands to ask questions and/or share opinions. The students were not always cooperative in the teachers' attempts to allow them to perform more activities and to self-construct their own knowledge. They were familiar with the old lecture based approach in which they were told exactly what to know and were unsure of this new hands-on approach. This sense of being uncomfortable with these new approaches by their teachers is likely due to the fact that every year in every area of science, they have had their teachers lecture to them and provide them with knowledge without much effort on their part until exams. This new way meant they had to be "on" every single class and this meant more work, more thinking, and more constructive interaction with their classmates. The students were not always eager to accept their new role.

This reluctant behavior on the part of the students is in line with the study of Segers and Dochy (2001 cited in Gijbels *et al.*, 2006) who described students' perceptions of how they should be taught based on their prior learning experiences and recent experiences. Dochy *et al.* (2005: 29) stated that "students' conceptions of learning and knowledge are often challenged because the situations in which they are expected to be creators of their own knowledge seldom occur and thus they are inexperienced in this type of learning". Likewise Chang, Hua and Barufaldi (1999) provided more support by referring to students' comments on the student-centered teaching practices in which they stated that they were more enjoyable and probably had value, but they were concerned as to whether they were acquiring the content knowledge they would need to pass their exams which was the most important goal in their eyes and for this reason they showed preference for the teacher-centered approach.

> Student perceptions of the constructivist-inspired teaching method demonstrated some frustration on their part; they realized the advantages of this type of instruction in terms of it stimulating and increasing their thinking skills and other process skills, yet, they did not see this type of instruction as being promising because it seemed that it would not help them perform better on entrance exams. (Chang and Barufaldi, 1999: 382)

Dochy *et al.* (2005) scaled their results regarding student's reactions to more student-centered learning approaches as being more effective, but they were unsure that they would have enough content knowledge about the subject matter when it came time to writing examinations. These studies imply that implementing new teaching practices that more directly involve them in their own learning created problems for the students because this meant "change" for them as well and they were already used to the "old way". Students were comfortable with the teacher-centered practices and this sudden move to student-centered practices left them feeling a bit unsure or vulnerable especially when it came to passing important examinations.

Some studies however found a more positive result regarding students' acceptance of new more student-centered learning. These studies suggested that by providing supportive guidance, feedback on cooperative learning or self-directed learning it is possible to bridge the gap between students' perception of the conventional lecture-based format and the more constructivist mainstream teaching approaches (Gijbels *et al.*, 2006).

Considering cultural perspectives, Thai culture may shape students' perceptions of learning in which they are more comfortable with their teachers simply "telling" them what they should know without any questions or discussion involving them. It is longtime part of Thai culture that students show respect to their teachers and one way to do this is to not question anything they tell them. It is disrespectful to challenge your teacher and this is deep rooted in the culture. This means Thai students are typically quiet and are not allowed to talk in class and certainly not encouraged to ask questions or give their opinions in class. This culture behavior can be seen in other Asian countries and it results in the same student expectations of their teachers and their own role in the classroom. This situation is consistent with numerous studies on the impact of culture on students' cognition, or achievement (Chang, Hsiao and Barufaldi, 2006). These features generate a source of discomfort for teachers to become facilitators rather than simply managing students learning environment. To implement integrated lesson, teachers shifted their teaching practice they one taught.

> …Even if teachers have a strong content knowledge and belief structures that are well aligned with the constructivist perspectives…they are not guaranteed to be free of discomfort … (Frykholm 2004: 136).

Geology teachers integrate connected science content by using analogies familiar to the students

The use of analogies can support student learning by giving them a concrete model of something that is quite abstract to them. Analogies can make the unfamiliar familiar and turn abstract knowledge into known knowledge (Gentner and Gentner, 1983 cited in Blake, 2004). Ready made materials or actual events can be used as analogies to facilitate the understanding of science concepts. In Geology teaching and learning resources that allow the interplay of other science concepts with its content should put emphasis on using simple ideas that can reproduce geological processes and make them easier for learners to understand. *Ms. Kanokpon* and *Ms. Sunee* attempted to use materials that were familiar to students' from their day-to-day experiences to be analogous with the Geological processes that occurred in nature. For example; the use of the movement of boiled water to represent the process of convection currents that underlie the Geological processes regarding plate drifting or sliding bricks to represent the friction exerted between the forces that drive plate movement. *Ms. Pimpon* used the analogy of wave propagation in water to resemble the movement of seismic waves as they pass along the Earth's crust when an earthquake occurred. These teachers also used a variety of activities to assist in the integration of Geological concepts with concepts from other areas of science. *Ms. Pimpon* used fossil records to investigate past environments and the living things that existed in different geologic time periods. Physical artifacts in rocks is a record of the living things that once existed ant this is a key to understanding the past, thus, students could infer from this what the Earth used to look like. This type of activity gives students an opportunity to model the same methods of inquiry that Geoscientists pursue in reality (Kastens and Rivet, 2008). Geological content is composed of many abstract processes that occur in the nature which are not directly accessible for the students to experience. To support the students' understanding of these complex processes a cause and affect analogy can prove to be very useful (Newton and Newton, 1995; Blake, 2004). As Baker (1996 cited in King, 2008) suggests familiar human events that can be explicitly directed with geology concepts:

> The science of Geology has long concerned itself with the real-world natural experiences of the planet we inhabit. Its methodology more directly [than that of some other sciences] accords with commonsense reasoning familiar to all human beings (p.192)

However, it is possible that the linkage of scientific principles and real-world experiences is a "double-edged sword" (Davis, 2003). In particular, some links could be good sound representatives of scientific principles while the others may be only partly related. Discussion among students about which aspects of Geology or other science content models are representing needs to be conveyed to the students as well as the aspects that are not being represented by the model so confusion does not occur. The flaws or imperfections of models being used to resemble a natural occurring phenomena need to be pointed out by the user to there audience (Newton and Newton, 1995). Students could misinterpret what the analogy is trying to tell them and result in many misconceptions developing. For example by using the idea of boiling water to model the processes of convection currents in the mantle might give the students the idea that the composition of the mantle is similar to water which is incorrect. Students need to have these issues pointed out to them and be made aware of the limitations of the model to truly represent natural phenomena.

Moreover, the maturity of the students should be considered in terms of their understanding in fundamental principles in the integrated ideas as reported in the Inter-Union Commission on the Teaching of Science (1968) which noted that when the fundamental principals are interwoven into core knowledge the maturity of the learners should be considered. Even though they might be able to understand what they are seeing in terms of the analogy, the chosen analogy should correspond to the degree of comprehension of the students. The students might vary in age, gender and experience from previous classes they may not all be able to understand the fundamental principals they are being exposed to and therefore not able to gain insight into to integration. Thus teachers need to ensure that any subject integration that occurs is congruent with the students' experiences. It cannot be too far beyond the knowledge that they already possess or they maybe incapable of making the correct connections.

The tension of content coverage as outlined in the curriculum as it relates to time limitations and irrelevant assessment programs such as final examinations having more affect on implementation of integration in the study of Geology

In the real classroom and real students can serve as obstacles for enacting integrated curriculum as planned by the teacher (Czerniak *et al.*, 1999). All three teachers who participated in the study illustrated concerns about being able to cover all the required content in a limited amount of time. Scheduling block classes was a big challenge and as because of the already established timetable, they often could not implement their designed lessons because of limited class time. In *Ms. Kanokpon's* situation she could not finish the entire activity regarding the boiling water and the behavior of convection currents and had to skip over several major scientific processes because she simply ran out of time. She felt she had to cover all the curriculum the activity should cover as well as have the students reflect back on their thoughts about what was happening and all this was too much to accomplish in the time she had. *Ms. Sunee* had the same problem when she tried to use integration she was unable to complete her lesson plan. She had to wait for the students' responses to her questions and then allow them to build the links between those and the content before she continue on with the activity. She ended up going into "marathon talking mode" to get all the content across to them before she ran out of class time. *Ms. Pimpon* and *Ms. Sunee* relied on text materials to cover the Geological content using it as a post-writing task and not just a reading exercise. These tasks more emphasis on content-related learning rather than using student-generated diagrams in which the students could make inferences (Gobert, 2000). Time remains a large hindrance to teachers implementing the whole complete process of an integrated lesson. Teachers are too concerned about covering all the topics and content and thus time is a factor in selecting what content knowledge will be taught and which activities will be implemented and which ignored.

This finding is consistent with the numerous literatures written on integration. Beane (1995) was convinced that the fear of content coverage in curriculum influences the adoption of integration in classrooms. As regular curriculum with separate discipline is overcrowded with content to cover, teachers feel that they do not have enough time to convey content in an integrated manner in their classrooms (Lehman, 1994 cited in Czerniak *et al.*, 1999). Further, the pressure of high-stake standardized tests might also be a factor in hindering the implementation of an integrated unit. Most standardized tests concentrate on fragmented content knowledge which usually contradicts to the emphasis of relevant knowledge and skills in an integrated fashion (Czerniak, 2007). She concluded that

> …for integration to be widely accepted in a standards environment, either standardized tests need to measure knowledge and skills associated with learning in an integrated manner or integrated units need to be developed commercially and teachers need to make assessments consistent with those in the standards and on high-stakes tests (p.554).

In particular, students in the upper secondary levels who decide to enter a science-based faculty in a university or to pursue future science-based careers emphasize in the system where individual sciences are taught quite separately.

Content integration interconnects relevant science concepts among physics, chemistry and biology but, several concepts are excluded. Teachers' confidence to teach unsure concepts should be considered.

All the teachers in the study attempted to design lesson plans that integrated other science concepts related to Geology. Using a wide range of activities such as hands-on activities, teacher demonstrations, three-dimensional models or self-directed reading materials these types of activities gave the students opportunities to integrate relevant science concepts with the Geology concepts. In particular the concept of wave behavior is a fundamental physics concept necessary to understand the nature seismic wave behavior during an earthquake. *Ms. Kanokpon* and *Ms. Sunee* provided demonstration of a model slinky to demonstrate the horizontal motion of particles, while *Ms. Pimpon* implemented a hands-on activity using water with pieces of paper floating on the surface to show the vertical movement of particles. It is possible that students could learn the concepts related to wave behavior through different kinds of context (Rakkapao, Arayathanitkul and Pananont, 2009). Physics concepts are quite prevalent in Geology concepts especially those that deal with Earth processes. A study by King and Kennett (2002a, 2002b), showed that physics and Earth sciences share many relevant concepts and should therefore be taught together. Aldridge (1993, cited in Chang, 2005: 627) stated that "chemistry and physics are fundamental to an understanding of the life sciences. And chemistry, physics, and life sciences are fundamental to an understanding of the Earth and space sciences".

The teachers in the study did make attempts to integrate related concepts from other science disciplines in their teaching of Geology, but they felt uncomfortable in doing so because of their perceived inadequacies of the Geology content. *Ms. Pimpon* allowed her students to examine different fossils, both real and models. *Ms. Sunee* used reading sheets and thus her student simply investigated their physical appearances, age, or living habitats. Neither teacher discussed the related biology concepts such as the evolution underpinning the fossil evidence and what it tells regarding Geological time periods. This goes a long with the study of Veal and Kubasko (2003) which stated that Geology teachers had fewer concerns about teaching evolution concepts. They thought that the topics were “more historical and inanimate”. They perceived that students might not be interested in evolutionary concepts by observing the dead fossil record in rocks, and not see its relationship with human life if it were taught in biology class. Likewise, the study of Trend (2001) found that pre-service teacher were unlikely to encounter the topic of evolution, particularly the topic of evolution in humans. They felt this topic was too complex or controversial to study in Geology.

Another example that used physics concepts wave the seismic wave activity. *Ms Pimpon* lack of confidence to teach unfamiliar content influenced her decision to enact the integration of certain knowledge. In group meetings and interviews, *Ms. Pimpon* was the only teacher was clearly concerned that her low level of understanding in other science content areas would hinder her teaching practices. She was conflicted about her discomfort because it limited her teaching practices. This is consistent with what Shulman (1987 cited in Abd-El-Khalick and BouJaoude, 1997:) noted “the methods of instruction used in the classroom are related to the teachers’ content knowledge, and are influenced by their personal understanding of the subject matter. Evaluation follows instruction and requires a firm grasp of the subject matter”. It is possible that teachers’ background knowledge influences their decisions of implementing which methods to teach their students. The English National Curriculum for Science, the USA of inquiry and the National Science Education Standards (National Research Council, [NRC]) showed that the inclusion of ‘scientific enquiry’ provide a greater chance for all students to participate in scientific investigations if teachers have ‘strong Geo-scientific background’ which is not the case for most Geology teachers (King, 2008). To put aside their fears of insecurity and take on some risk teachers have to increase their confidence in content knowledge areas (Braunger and Hart-Landsberg, 1994).

Ms. Pimpon handled her insecurities regarding her lack of expertise in some content areas by asking for help from her colleagues. She pointed out her intention to teach Geology with other science teachers, however, they did not have time to plan and coordinate these lessons together because of the teachers' already heavy workloads. Her students therefore might not experience lessons of integration because there was no attempt to have conversations on how to teach physics principles in geology content with her colleagues because of the limited amount of time available for them to collaborate. Collaboration among teachers has large influence on whether integration of content happens (Inter-Union Commission on the Teaching of Science, 1968; Gunn and King, 2003 and Elayne and Dempsey, 2008). There are several levels of collegial relations ranging from very weak perhaps a quick conversation in the hallway to very strong in which teachers work jointly together to teach (Little, 1990 cited in Jang, 2006). *Ms. Pimpon's* collaboration was at the low end of the continuum in that she only asked for assistance without there really being anytime to sit down and plan lessons together with her colleague. If teachers can work on the other end of the continuum for collaboration it can result in a shift from individualistic teacher focused approaches like teacher-centered ones to more collective approaches which usually improves teacher confidence and leads them to towards trying new kinds of teaching techniques (Abell, 2000).

CHAPTER VI

CONCLUSION AND IMPLICATIONS

Introduction

This chapter contains a review of the research framework used in this study, the conclusions of the study's findings, their implications to practitioners, and suggestions for further research. The first part of the conclusions of the study describes the current teachers' teaching practices in Geology in the first phase of the study. The second part of the conclusion section describes the changes of teachers' teaching practice when participating in the CAR group, the second phase of the research study. At the end of the chapter, are some suggestions for conducting further research are presented.

Review of the Research Framework

The teaching of Earth science or Geology in past curriculums has received much less emphasis than the traditional science disciplines of physics, chemistry and biology. (Orion *et al*., 1999a, 1999b) The present National Curriculum Standards (IPST, 2001) are more aligned with educational reform and the study of Earth science is now a mandatory component of the science curriculum for all science students in elementary and secondary school. Earth science has been recognized to be equivalent in importance and necessity as "Earth science for all" and not just for specific groups of students. Teachers have to face the challenge of teaching with a new curriculum which also calls for more integration between the different science disciplines in order to promote students' understanding of how the world truly functions and that all knowledge regarding it are interwoven. This study therefore consists of two phases. The first phase carries out the task of trying to understand current teachers' teaching practices in Geology their use of teaching and learning materials, assessment and evaluation methods, and their use of an integrated curriculum. Three Geology teachers (Ms.Pimpon, Ms.Kanokpon, and Ms.Sunee) from different public schools participated in the study. The researcher in the study conducted classroom observations, interviews, examined teachers' lesson plans, and examples of their students' work to obtain insight into each of the teachers' teaching practices

In the second phase, the teachers and the researcher created the collaborative action research (CAR) group to be a place for practitioners, the science educator, and the researcher to work together because professional development increases the empowerment and give teachers' ownership of their own learning in a safe collegial way. The CAR group meetings took places regularly once a month in an open environment where teachers could share their teaching experiences, discuss problems they may have teaching, and to give them the opportunity to suggest valuable ideas that may help solve problems. Further group meetings gave the teachers opportunities to build relationship among themselves, help in designing new lesson plans, and to reflect on the teaching of them. Action research occurred when an individual teacher designed lesson plans to correspond with the integrated curriculum from collaboration within the group and implemented it in his/her classroom situation. Once, the lesson plans were implemented in the classroom, the teachers got together to critically reflect on their teaching. They shared their experiences with the CAR group and members learned from each other when they reflected upon what happened in the classroom and revised their lessons plans. Collecting data in this phase relied on conversations in the CAR group meetings, classroom observations, post-class interviews, and the teachers' lesson plans (Figure 6.1). Inductive analysis of the data initiated the pattern to build the data into categories and themes. Multi-case studies demonstrated by the teachers' teaching practices were separated into several themes.

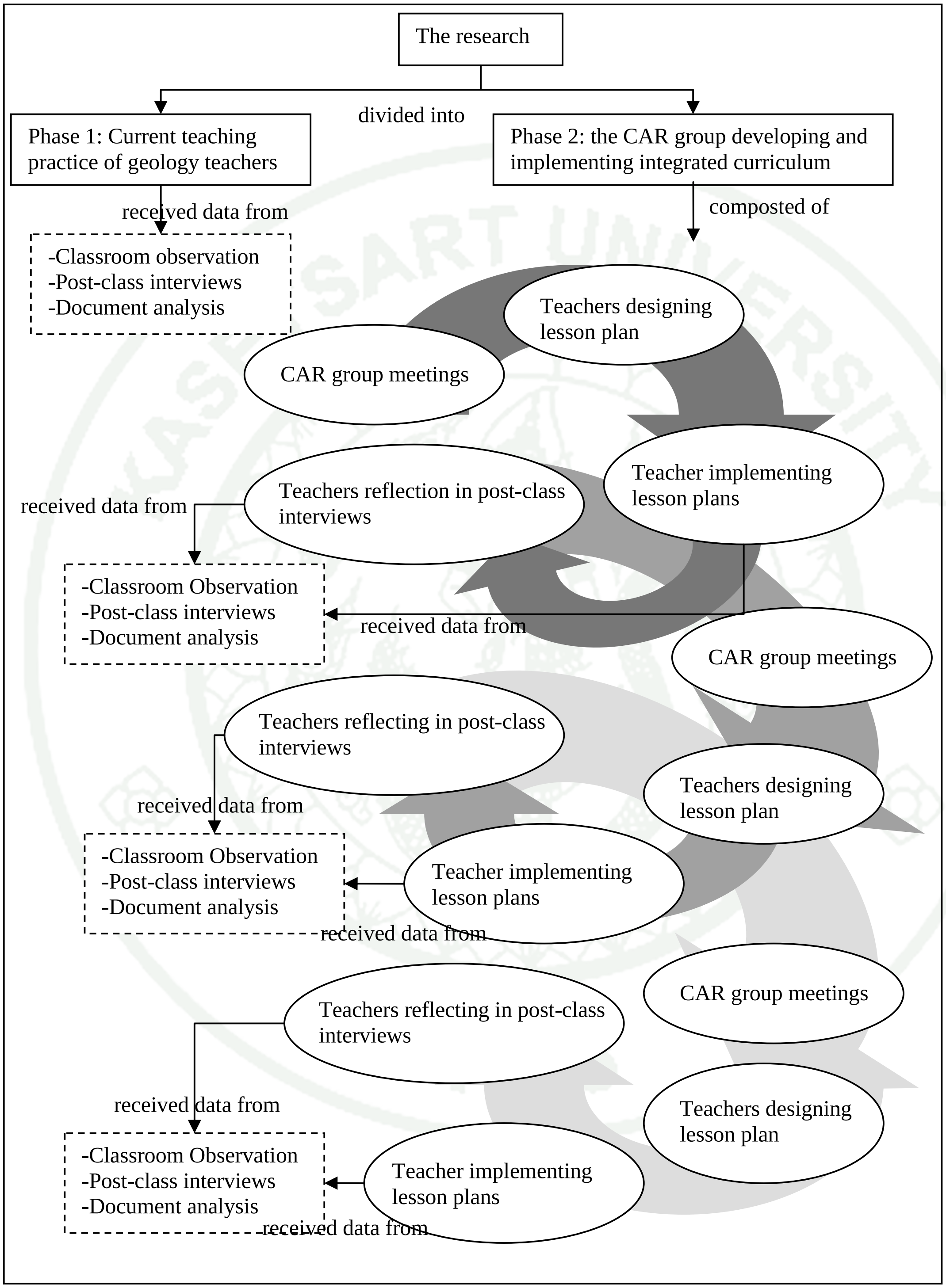


Figure 6.1 Summary of Research Framework

Conclusion of the Study

First Phase: Current Practices of Geology Teachers

The current teaching practices of Geology teachers in the 2008 academic year in the upper secondary levels was not consistent with the goals of the National Science Curriculum Standards B.E. 2544 (IPST, 2002) in several ways. All the teachers in this study employed traditional teaching methods in or to transmit Geological content to their students, but differed in frequency and reasons for choosing the lecture-based method, implementing teacher-led discussions, text-based instruction, or lack of experiments. Ms.Kanokpon held a strong belief on that the teaching of Geology should primarily concentrate on simply giving the students the content knowledge by telling it to them. She believed that the 'talk and write down' format was the most appropriate method for students and that searching for information was also suitable to learning Geological content. These beliefs were based on the fact that there was an enormous amount of content that needed to be covered in a short period of time and these two tenets decided her teaching practices. Thus, hands-on activities such as experiments were neglected because it contradicted with her view that the nature of the Geology content is not congruent with that kind of activity. Ms.Sunee felt pressured to use the lecture format again because of time limitations but additionally because of the lack of appropriate school facilities even though she was aware of the importance and necessity of providing an active learning environment for her students. She used the IPST textbooks as the main content resource and had the students search for information which they presented in a report as an in-class discussion to support the IPST content. Additionally, she made printed materials for the students to read independently prior to the term exams if she ran out of time to cover all the content in class. Ms.Pimpon's practices revolved around the text-based worksheets she gave the students. The students were encouraged to explore on their own and answer the questions on the worksheet by using their textbook as the prime source and some diagrams or illustrations she had displayed in the room. Some of the worksheets put emphasis on knowledge that had or would appear in national examinations because of her concern that the school maintains its high academic record. Although she provided opportunities for the students to do some hands-on experiments, she frequently played a central role in the recording of the data, leading any discussion, and drawing conclusions so she could cover all the topics she had planned with the time limits of the period. Time constraint was a huge contextual factor influencing all the teachers' teaching practices. Ms.Kanokpon said that the pressure of a large amount of Geology content forced her to teach like a tutor.

The use of teaching and learning materials in the Geology classroom varied in each teacher's classroom. The main resource was various kinds of models such as hand-made volcanoes and ready-made tool kits from the IPST which were analogous to natural settings or phenomena. Worksheets were another example of a learning material that provided the students with information they could use to do both in and out of class activities. The teachers illustrated the difficulty of running a Geology class without adequate materials especially the lack of real specimens and the difficulty in organizing field trips. In terms of assessment and evaluation procedures, all teachers used various methods of assessments but most were traditional tests, student worksheets, or students' notebook and were primarily used to make cognitive assessments regarding the students' learning while process skills and the affective domain were assessed less frequently.

In response to the call for the integration of relevant subjects to develop core knowledge throughout primary and secondary school levels this study aimed to integrate Geology's content into a broad range of subject matters such as physics, chemistry, and biology as all of these areas of science are really interwoven. However, from the findings, teachers currently neglected other relevant science concepts to Geology and continued to view science in a systematic and integrated way. Ms.Pimpon saw the integration of Geology with other non-science disciplines such as English and utilized simple activities to interrelate English with the Geology content. Ms.Kanokpon used simple questions to connect related science content when teaching Geology without encouraging the students' critical thinking skills. Ms.Sunee viewed an integrated curriculum as the connection of previous knowledge with new learned knowledge. Although an integrated curriculum has been in affect for a long time, teachers do not actually translate what the reform recommends into actual practice in their teaching situation.

Second Phase: Using the CAR for Developing and Implementing an Integrated Curriculum

All three participating teachers made progress in adapting their teaching practices according to their education background, experiences, beliefs, and school context when they entered the study. It can be seen that all three changed their teaching practices to become more student-centered in that their students' role shifted from being simply recipients of knowledge transmitted to them through listening passively to lectures, reading textbooks, and completing worksheets and lab handouts to being engaged in discussions, responding to teachers' questions, or doing self-direct learning activities from printed materials. Teachers arranged active learning environments for their students with recognition of the students' prior knowledge, using demonstrations, experimentation, self learning, and recognizing students' voices in class activities. However, all the teachers in this study did not drastically transform their teaching practices. Ms.Kanokpon's belief regarding the most effective method in teaching Geology persisted and she continued to prefer transferring knowledge to her students using the lecture format. Ms.Pimpon still used similar worksheets as in the first semester. Some activities designed in the new lesson plans were not completely implemented in class due to time limitations. The shift of teaching practices was also influenced by the teachers' encounters with low level students' engagement in the constructivist approach which contradicted traditional ways of learning. The use of teaching and learning materials involved the use of more of models of and reading sheets with post-reading exercises. The assessment and evaluation was almost similar to procedures used in the first semester but the additional post-reading sheets and diagnostic tests were used in the second semester.

1. The implementation of the integrated curriculum in classroom

From the results of the study, teachers were aware of integration in their teaching practices. They created a variety of activities to provide an active environment for students to make connections between related science concepts with Geology content. However, the students did not cooperate very well when they were actively engaged in activities in the classroom and thus the teachers would then have to lead discussions to point out key concepts of integration. A wide range of activities was utilized to convey the content integration of Geological phenomena into classroom settings. Ms.Sunee utilized an integrated curriculum with diverse hands-on activities. The students observed demonstration of models and in some occasions manipulated them independently depending upon time availability. The teacher saw that activity-based learning helped the students to better comprehend integration in Geology. Furthermore, Ms.Pimpon attempted to include hands-on activities related to physics concepts when teaching about seismic waves but she encountered the problem of her lacking a strong content knowledge of these concepts which related to the Geology contents. She dealt with the problem by asking for assistance from her school colleague to explain the physics concepts that she was not comfortable with. Ms.Kanokpon retained her belief regarding her traditional form of teaching and learning Geology and thus she was reluctant to change her practices even based upon what she had learned from the CAR group meetings. No matter what though the teachers could not follow all the procedures in their lesson plans because of unscheduled situations such as school activities resulted in shorter class time. Ms.Sunee said that although implementing an integrated curriculum needed more effort and time to design and to prepare activities, it was essential for teaching Geology. Ms.Pimpon said she improved her content knowledge in other fields of science when using an integrated curriculum.

2. Collaborative learning from the community of the CAR group

The teachers in this study demonstrated their professional growth from participating in the CAR group in different ways. The CAR group meetings provided the teachers with a safe place for them to learn from each other’s experiences. In the area of content knowledge, the teachers contributed interesting ideas and additional knowledge. Additionally, the discussion that occurred in the planning stage about how to teach particular Geological topics using suggested teaching and learning materials, or how to assess and evaluate students’ learning was extremely helpful for the participants. The sharing of knowledge and experiences was the main component of the group’s collaborations. Each teacher designed individual lesson plans congruent with their educational background, their students, and the classroom context. In the implementation stage some teachers could not follow what they had learned from the CAR group in their classroom because of time constraints, a low level of student engagement, or their own strong contradicting teaching beliefs. They reflected on their teaching practices after implementing the integrated curriculum and shared their experiences with each other. Ms.Sunee said that she learned more about how to integrate Geological content with other science content from her collaboration in the group. Ms.Pimpon learned to adjust her teaching worksheets to provide meaningful learning for students.

Implications of the Study

Implication of implementing an integrated curriculum in the upper secondary levels

In general, utilizing an integrated curriculum is prevalent in the primary levels or lower secondary levels because the science discipline at these levels does not explicitly make a distinction between the different science areas. In regard to school structure and the expectations of the community, they press teachers and students to concentrate on fragmented learning into solitary disciplines. Integration could be viewed as the ideal theory for current education but many teachers are reluctant to put it into practice. To overcome these barriers, teachers must view integration as a worthwhile goal and believe in the value of integration as it affects students' learning. Initially, individual teacher are the starting place for an integrated curriculum to be utilized. Teachers create activities that provide the students with opportunities to interconnect many science concepts with Geological ones in the classroom but this takes a considerable amount of time and effort on the part of the educator to design the lessons and plan the activities. It also involves creating networks and collaborating with colleagues whether they be science teachers or others perhaps team teaching to support integration.

The findings of the study illustrate the effect that content knowledge has on the implementation of an integrated curriculum. None of the teachers who participated in this study had a strong background in Geology because the teachers' colleges and university faculties from which they graduated did not include the study of Geology in their curriculums. It is essential for teachers to attend courses or workshops that provide them with Geological content and give them the opportunity to use geological skills in the field. Teachers must be involved in an active experience in the field in order to model the work of geologists so they can apply the skills they acquire from this type of experience to their classroom teaching. Geology possesses distinctive skills such as large-scale thinking, geological reasoning using a historical approach or spatial reasoning skills (King, 2008). Furthermore, as teachers become increasingly more of an expert in the geological content, they can view the systems of the Earth and recognize the interrelationship of the knowledge involved to other areas. Once teachers see the “big picture” that is Geology, they can organize teaching practices to involve integration and pass this onto their students.

The result of this study is not to generalize and fit its conclusions in the context of all schools, teachers, or students. The participants’ lesson plans and teaching practices were different according to their individual backgrounds’, their teaching situation and their school facilities. Each school’s situation had its own idiosyncrasies in which an integrated curriculum could be implemented using different ways of teaching. If the schools are surrounded by or near learning centers, museums, or geological sites, teachers could use these out-of-school locations to provide field activities for the students to see directly the relationship between various different subjects they learn at school and how they relate to the concepts of Geology. For instance, students in schools located in North Eastern Thailand will benefit from doing fieldwork at an excavation site that contains extinct dinosaur fossils. Also in Northern Thailand there are several major fault lines running through that area which drives the areas geological phenomenon such as hot springs and volcanoes. Students in these rural areas might become very interested on learning more about these invisible processes that occur beneath the surface of the Earth upon which we humans live. Urban schools do not have these environments readily available and therefore their teachers need to seek other methods to make the geological processes more “real”. Models or multi-media resources could replace direct field experiences and teachers could use teaching and learning materials to illustrate related concepts in different contexts respecting of course budget restrictions and the availability of materials. Teachers can use inexpensive materials instead of the costly ready-to-use tool kits from national curriculum agencies. Non-profit organizations such as the Department of Mineral Resources, Ministry of Natural Resources and Environment, is an agency that supports teachers by providing them with quality teaching and learning materials developed by geologists.

Implications of creating a collaborative action research group among teachers to transform their practices

Collaborative action research conducted by experienced teachers helps the growth of professional development to achieve the call for changes in both content and methods of instruction (Christensen, 2005). It differs from conventional forms of professional development which ignore the ongoing process of tracing the changes in teachers' teaching practices. This study was limited by the small number of teachers who are responsible to teach geology in the upper secondary levels in Thai schools as there is usually only one teacher doing this in each school and thus collaboration in the same school is less likely to happen. Collaboration amongst Geology teachers in nearby or networked schools could occur but there has to be support from educators or administrators to allocate scheduled time and personnel to allow this to happen. Schools in which there is more than one Geology teacher should encourage them to work together to plan lessons, share their experiences, and reflect upon their thoughts on teaching geology. This is the best way to develop a learning community in the workplace and to do action research in the school context. It is now widely accepted and supported by numerous studies that action research implementation is the best way to improve teachers' professionalism with respect to their knowledge and experiences. Thailand like elsewhere, expects that teachers are to play the role of teachers as researcher in their own classrooms. Continuing ones professional development is an essential part of the teaching profession and it is this way that it will become a highly respected profession as is consistent with the educational reform outlined in the National Education Act B.E. 2542 (1999) (ONEC, 1999).

Suggestions for Further Research

Conducting Collaborative Action Research is useful but challenging

The teachers in this study learned how to change their practices from the team members of the CAR group and from the support of the science educator and the researcher. Knowledge and information regarding teaching methods received from other teachers are valuable to them to order for them to initiate effect classroom practices in geology. Sharing lesson plans, learning activities, or reflective feedback on teaching experiences can help teachers improve their own actions. However, strong collaboration of teachers was not frequently seen from the CAR group meetings. Teachers might feel uncomfortable to talk about their practices, to discuss their problem, or to share interesting ideas with their team members. It is possible that school culture impedes collaboration among colleagues in their workplace. Teachers are familiar working in isolation and rarely discuss their practices or problems in class with each other. Teachers should seek out their colleagues for collaboration as a positive situation for sharing and discussing.

Furthermore, collaborative action research could easily occur between teachers in the same school because meeting times could be conveniently scheduled. This flexibility could allow the teachers to meet more often and eventually become comfortable to talk openly sharing ideas and suggestions. Good collaboration amongst colleagues needs sufficient time to build trust and develop relationship among the teachers and as a result of this trust be more likely to use pedagogies learned from the group in the classroom (Maldonado, 2002). Unfortunately, this study took place over a short time, one semester and therefore did not have the time to establish long term collegiality.

More research centering on teacher development should be conducted on a regular basis. This study did not commit the teachers to do rigorous research or publish a final report from their studying. This research put emphasis on the methods that teachers used to collect data and reflected on these practices. Teachers should examine thoroughly their own practices from observing their students' responses or classroom interactions. Further research should encourage them to perform their own research, generate their own research questions, design methods of data collection, analyze data, and make conclusions. It should be the first order of action research to have the teacher develop a self initiated research question study it themselves and move away from having university researchers involved. (As defined in Capobianco and Feldman, 2006)

Teachers using an integrated curriculum require support in several ways

This study was a starting point for teachers to recognize the importance of integration in the teaching of Geology. In order to effectively use an integrated curriculum teachers need a strong background in the content area they are teaching and skills related to the science areas. Integration can then go beyond just happening with one teacher in one classroom to teachers working cooperatively with others who have more expertise in science to develop an integrated curriculum that could eventually lead to team teaching situations.

Many teachers are not confident teaching subjects they have never taught and thus they need appropriate content support from facilitators, but this support should correspond with the teachers' interests and demands. Without this the facilitators could diminish the ownership of teachers' professional growth which might result in negative feelings about the process by the teachers. Geologist or university specialists should be part of the collaboration group there to assist teachers on unsure concepts, to help teachers try out new teaching skills or find answers to their questions. In other words, provide support and not dictate change. None of this will guarantee the successful implementation of an integrated curriculum because their lack of science knowledge might still be a barrier. Further research should be done on the affects of pedagogical content knowledge (PCK) on using an integrated curriculum. The support for content knowledge would be an interesting focus because of its influence on improving integrated curriculum in their practices.

Further research should also occur over a longer time period, two semesters or more in order to better study the effects of implementing an integrated curriculum.

One semester, the time period in this study, was not long enough to completely develop the curriculum, implement it and then reflect upon its implementation. Six or Seven weeks of Geology classes is a very short time for teachers to try out their new roles, use new activities and experience new student responses. All the stakeholders in this implementation need time to adjust to it and need to have ongoing support from the researcher to ensure they are on track. Long-term research would benefit the continued efforts of teachers' to use the integrated curriculum and their use of the suggestions implied in the curriculum. This study also focused on the growth of teachers' professionalism when they participated in the CAR group as it related to developing an integrated curriculum. Further research should investigate students' learning and their responses when they are exposed to an integrated curriculum. Their responses could help in the development of future integrated curriculums.

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APPENDIX

Interview Protocol

An interview protocol to explore current Geology teachers' teaching practices

1. Could you please describe your education and experience in teaching in science and geology
2. Could you please describe your teaching method to teach geology in the upper secondary levels? Why?
3. Could you please describe the use of teaching and learning in teaching geology? Why?
4. How did your students response to that teaching methods
5. How do you assess and evaluate student understanding of geology
6. Could you please describe the using integration in your teaching practice?
7. What are your difficulties in teaching geology?

An Interview Protocol for exploring teachers' reflection on Geology teacher's teaching practices

1. Could you please reflect your practice on today lesson?

2. What do you think is there dissatisfy on your practice?

3. Are there any problems or difficulties on your practices on your today lesson?

4. Could you describe how could your solve the problem?

BIOGRAPHICAL DATA

Name:	Miss Benjawan Hanpipat
Date of Birth:	July 22, 1982
Place of Birth:	Lamphun, Thailand
Graduation:	-B.Sc. in Physics, Chiang Mai University -Diploma in Education in Science Education, Chiang Mai University
Conferences:	-2009 The ASERA 2009: 40th Australasian Science education Research Association Conferences, Deakin University, Geelong,, Australia -2008 The 34th Congress on Science and Technology of Thailand (STT 34), Queen Sirikit National Convention Center, Bangkok, Thailand -2008 The Investigation Our Practices (IOP's): 11th Annual Conference, University of British Columbia, Vancouver, Canada
Scholarships:	-The scholarship to pursue a doctoral study at Kasetsart University under PSMT, Royal Thai Government and IPST