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THESIS

ENHANCING THAI CHEMISTRY TEACHERS' TEACHING FOR CRITICAL THINKING THROUGH A PROFESSIONAL DEVELOPMENT PROGRAM

KANLAYANEE PUNBO

A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
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Kanlayanee Punbo 2011: Enhancing Thai Chemistry Teachers' Teaching for Critical Thinking through a Professional Development Program. Doctor of Philosophy (Science Education), Major Field: Science Education, Department of Education. Thesis Advisor: Assistant Professor Naruemon Yutakom, Ph.D. 233 pages.

This interpretive case study examines how a professional development program (PD) on teaching for critical thinking (CT) enhances chemistry teachers' understanding and teaching practices for CT. Three chemistry teachers who taught grade 10-12 participated in the study. The PD program was composed of two Phases. Phase I examined teachers' prior understanding of and teaching practices for CT and developed workshop activities based upon their understanding and practices. Phase II examined how the teachers applied their knowledge from the PD program into their teaching practices. The data gathered included: classroom observations of teaching practices, interviews with teachers, teacher group meetings, teacher reflective journals, teacher questionnaire, lesson document analysis, and interviews with students. Each teacher comprised a case and a cross-case analysis was carried out.

Results from the study indicated that the teachers' prior understanding of CT could be characterized in terms of abilities to answer questions with supporting reasons and to apply Chemistry knowledge in real-life. Their practice could be characterized as teacher-driven and content-driven instruction. Based on analysis of the data, following the PD activities, the teachers showed a greater understanding of and teaching practices for CT. The following teaching practices were observed: conducting interactive classroom activities, using questions that showed evidence of challenging students to provide reasons for their responses, engaging students in hands-on and minds-on activities, using high cognitive tasks, and authentic assessment. Important features of the PD program included: a year-long participation, focusing on collaborative learning among teacher participants and between the participants and the researcher, providing an intensive workshop on teaching for CT in Chemistry, in which the participating teachers gained experience in teaching in the context of teaching for CT in Chemistry.

The results of the analysis suggest that the PD program with the above features can be valuable to enhance teachers' understanding of and teaching for CT. However, further studies should examine the extent to which these changes are sustainable over time. To meet the Thai National Reform goals of promoting students' CT, a further study should investigate the effects of teachers' use of CT teaching strategies on students' learning and thinking abilities.

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Student's signature Thesis Advisor's signature

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Kanlayanee Punbo
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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (CONTINUED)

Page

TABLE OF CONTENTS (CONTINUED)

Page

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

This study investigates how the implementation of a designed professional development program (PD) is valuable to chemistry teachers' understanding of and teaching practices for critical thinking (CT). The PD program was implemented in 2 out of nine upper secondary schools around the Nonthaburi Education Service Area Office 1, Nonthaburi Province, Thailand. The implementation of the program and gathering of data took place during the academic year 2009. The study aims to answer two main research questions including: 1) what are chemistry teachers' prior understanding of and teaching practices for critical thinking? And 2) how does a designed professional development program affect teachers' understanding of and teaching practices for critical thinking? This chapter addresses the statement of the problem, research purposes, research questions, anticipated outcomes, delimitation of the study, and definitions of terms. At last, the chapter provides organization of the thesis.

Statement of the Problem

Promoting students in thinking abilities is an important educational goal across current curriculum topics, including those found in science education (Zoller, Ben-Chaim, and Ron, 2000b; Bailin, 2002; Pitagsalee, Kiokaew, and Meechan, 2007). Construction of a knowledge-based society is the main emphasis of Thailand's educational reform (Office of the National Education Commission, [ONEC], 2002). The National Education Act B.E. 2542 was declared in 1999 which is seen as a framework and guideline for Thai education endeavors to develop desirable students who are able to collaborate creatively and employ higher order thinking in the current circumstances (ONEC, 2002). Attention has hence turned towards the education of teaching for deep understanding and thinking as the great driving force for students' development of their abilities in the cognitive, affective and psychomotor domains (Khaemmani, Kanchanawasri, Techakupt, Wittayasririnon, Chaowakeeratipong, and

Theeranuruk, 2001). The promotion of students' thinking abilities has been clearly indicated as an important government document, as suggested below. One main aims of science teaching and learning in Thailand is to develop students' CT capacities, imagination, ability to solve problems, ability to manage data, ability to communicate, and ability to make decisions, and science process and thinking skills (The Institute for the Promotion of Teaching Science and Technology [IPST], 2002). According to the National Education Act B.E. 2542 (1999) and Amendments (Second National Education Act B.E. 2545 (2002) in Thailand that have traditionally served the role as master law of national education (ONEC, 2002), instructional performance shall concentrate upon students' learning capacities. As well, all learners should have opportunities to engage in all learning that will serve to stimulate their interests. Section 22 of the National Education Act B.E. 2542 addresses the national education guidelines for all teaching and learning, and states that, "Education shall be based on the principle that all learners are capable of learning and self-development, and are regarded as being most important..." Students, of course, are expected to be nurtured in their CT abilities. As section 24 of the National Education Act B.E. 2542 also elaborates that, educational institutions should organize learning experiences for students along with training them in thinking processes, as well as enable them to think critically. Focusing on teaching science in Thailand, the National Science Curriculum Standards B.E. 2544 (2001), based on the Basic Education Curriculum B.E. 2544, indicates that the teaching of science should accomplish the goal of developing students' capacities in scientific knowledge, the nature of science and technology, science process skills, and thinking and communication skills.

As documented intently in the National Education Act B.E. 2542 (1999) in Thailand (ONEC, 1999), in the section of Educational Standards and Quality Assurance, educational institutions shall be assessed educational standards by an Office for National Education Standards and Quality Assessment (ONESQA) or other qualified external organizations. For example, standard 4 of the external quality assurance aims to assess students' abilities in analytic thinking, synthetic thinking, critical thinking, creative thinking, and having vision (ONEC, 1999). However, it was reported that most of Thai students still have difficulties in thinking abilities;

especially, critical thinking and solving problems (**ONESQA, 2003;** Pitagsalee *et al.*, 2007). Khaemmani (2009) argued that students who are good in basic skills and knowledge based on a subject may be poor in parts of the subject requiring students' thinking and reasoning abilities. Consequently, it is a major goal of education reform to develop students' CT which it supports a great deal of their academic learning. Critical Thinking also contributes students to "know what, know how, and know why". To increase students' abilities in CT, an important factor is teachers' understanding of and teaching practices in the context of teaching for CT. What teachers' beliefs and understandings always results in how they practiced in their teaching. Consequently, teachers' classroom practices affected largely on students' learning and critical thinking (Torff, 2005; Torff and Sessions, 2006; Roehring and Garrow, 2007).

The precise meaning of CT is somewhat controversial at the present time. Consensually, CT appears to relate with ability of accuracy and validity evaluation of something (Ennis, 1985; Chatkup and Chuchart, 2001; Khaemmani, 2009). For instance, one definition of CT based on a revised Bloom's Taxonomy of cognition has been identified as abilities to apply, analyze, evaluate, and create things (Amer, 2006). Ennis (1985) also noted that CT is one's ability to think with reasoning: what should be done and what should be believed. According to Watson and Glaser (1964 cited in Sroymuk, 2004), CT consists of attitudes, knowledge and skills. Although there are varieties in the way to consider CT, most of them share similar ideas that CT refers to the complexity of deliberate, disciplined, purposeful inquiry-oriented, reflective, and evaluative thought (Zoller, Ben-Chaim, and Ron, 2000a). Therefore, a person can employ CT in the pursuit of relevant and reliable knowledge in order to assess the validity about the world.

Science curriculum should support the notion that learning activities in science should provide students opportunities in scientific inquiry along with the promotion of CT (IPST, 2001). For instance, students should have opportunities to design experiments to test a hypothesis. In addition, abilities to evaluate, interpret experiments, and draw conclusions from data as well as make predictions, and identify assumptions can enhance students' CT (Bailin, 2002).

Critical thinking has become one of the important skills embedded in instructional science. Sroymuk (2004) asserted that CT is the basis of all thought in making a decision properly about what to do or what to believe; a person is required to think critically. Students, who can think critically to design and perform scientific experiment, draw a conclusion, and evaluate answers to questions. Hence, thinking critically becomes a key element for making decisions and solving problems in various situations. Couros (2002) also stated that the absence of CT in students may bring undesirable consequences to the science classroom. For example, students may observe what changes occur in an experiment, but they have to "observe carefully" to arrive at scientific fact. Similarly, students can predict a rate of reaction, but they must think critically to "predict accurately" under conditions of the reaction (Bailin, 2002).

Science classroom and curriculum design can provide teachers with direction to help science students to acquire knowledge at the same time promoting students to think critically. In addition, another element to promote students' acceptable understanding and CT is teachers' teaching practices. Teachers still teach students based on traditional approach (Watts, Jofili, and Bezerra, 1997) which is viewed as a barrier in the promotion of students' meaningful learning and thinking abilities. Thus, teaching practices have become the focus of teaching and learning to enable students' CT (Roehrig and Garrow, 2007).

Teaching practice is arguably an important factor in promoting students' CT throughout the country. In order to design effective teaching-learning activities, it is necessary to significantly consider about three major components: the teacher, the learner, and the content (Eggen and Kaucbak, 1995). Davies (2006) stated that teaching CT should be integrated in during teaching other subject matter such as science and social science. He was supporting the infusion approach to teach CT, which is comparable with the general approach where supports teaching CT separately from other subject matter. According to the infusion approach, thinking can take place within diverse disciplines, and should be immersed in standard school subjects (Zohar and Dori, 2003; Moore, 2006). To be effective facilitators of meaningful learning, teachers have to reform their teaching practices, turning from teacher-centered to student-centered teaching and learning, because teachers have a major impact on the amount of students learn (Eggen and Kaucbak, 1995; Zohar, Degani, and Vaaknin, 2001; Barak, Ben-Chaim, and Zoller, 2007; Pitagsalee *et al*., 2007).

Effective teachers should be able to reflect their own teaching practices pertaining to the enhancement of student's knowledge and skills, while also attending to strengthening their own teaching strategies and practices. Section 52 of the National Education Act, B.E. 2542, stated that, "the Ministry shall promote the development of a system for teachers and educational personnel, including production and further refinement of this category of personnel, so that teaching will be further enhanced and become a highly respected profession" (ONEC, 1999). The publication of the Science and Technology Teacher Standards by the IPST in 2001 was documented as a consequence. This document intends to enable teachers' knowledge, performance, and abilities to enhance students' knowledge, thinking skills, learning processes, attitudes, ethics, and morals related specifically to the Thai context. In Standard 5 of Science and Technology Teacher Standards, science and technology teachers are expected to understand how to organize learning based on school curriculum that pays frequent attention to the development of CT. As well, the teacher must be able to develop and implement learning activities for CT (IPST, 2001). The attention of educational institutes in teaching and learning has focused more toward improving the quality of professional development (Pillay, 2002).

For productive teaching and active learning, teachers have greatly influenced what students learn and how to teach for students' thinking abilities both inside classrooms and outside schools. Teachers' understanding of "teaching for thinking" influences their teaching practices, frames what they learn and apply content from a professional development program (Zohar and Dori, 2003; Alazzi, 2008). Many studies have disclosed a certain common belief of teachers that CT activities are appropriate with only high achieving students, not for low academic achievers or for all students (Torff and Sessions, 2006; Punbo, Yutakom, and Meesuk, in press). Subsequently, teachers will not prepare tasks requiring CT for low academic achieving classrooms (Zohar and Duri, 2003). Such teaching practices might obstruct historically lower achieving students in developing their CT and also create a wider gap of ability between high academic achievers and their counterparts.

Some evidences hindering teaching for CT are revealed. Thai chemistry teachers also pointed to problems in teaching chemistry for CT such as the limitation of time, the lack of chemicals and science apparatus as well as teaching based subject matter for national examination (Punbo and Yutakom, in press). Though they suggested teaching methods to promote students' CT such as asking questions and doing experiments, in the practice teachers always used close-ended questions and answered the questions by themselves. Although the teachers did experiments with students, students did not participate properly in doing experiment; they did the experiments as following cookbooks (Punbo *et al*., in press).

Furthermore, Torff and Sessions (2006) surveyed factors which social studies teachers in Long Island, New York took into account in deciding when to use CT activities with low-advantage learners. They found that teachers preferred to use high critical thinking activities depending on issues of high-stakes tests, influence of administrator, and nature of the subject. Whereas, their preferences to use low critical thinking were based on issues of learners' prior knowledge, time constraints, influence of parents, influence of colleagues, learners' motivation level, and learners' ability level. Frequently, learning activities aim to motivate students' CT, but there have rarely sufficient methods to enhance teachers' capacity in how to employ such learning activities properly. Consequently, teachers cannot use such learning activities in effective ways; they still play their same roles, following a traditional teaching approach even in using such learning activities (Chatkup and Chuchart, 2001; Zohar and Schwartzer, 2005).

According to the Thailand education reform project (2002), Thai teachers still need necessary competencies including new types of knowledge, new learning strategies, assessment and evaluation practices, integrated teaching to improve students' learning outcome (Pillay, 2002). Yutakom and Chaiso (2007) investigated science teachers' views and needs for teaching and learning according to educational reform based on Thailand's National Education Act B.E. 2542 (1999). The participants involved science teachers who have taught in elementary, lower secondary, and upper secondary schools. A questionnaire of in-service science teachers' needs to develop teaching and learning accordance with the National Education Act of B.E. 2542 (1999) was implemented. The results suggested that teachers should develop a view towards teaching science that emphasizes inquiry processes, problem solving, problem processes, asking questions, and hands-on and minds-on activities to promote students' thinking skills including CT.

In Thailand, there are a few seminars or short-time workshops on teaching for thinking provided by educational institutes such like: IPST and Education Service Area Offices who are responsible to support teachers' teaching science and teaching for CT (Hanpipat, 2010). Most of research in Thailand relevant to teaching and learning for CT focused on development of CT ability tests, and researched the design and implementation of classroom activities promoting students' CT. For instance, Pitagsalee *et al*. (2007) studied effects of using inquiry cycle in science instruction on three groups of Mattayomsuksa one students' CT and satisfaction towards instruction. The first group was taught through inquiry cycle method, the second through inquiry cycle method then supported by activities for CT skills and the third group through inquiry cycle interspersed with CT skills. The findings indicated that the students who were instructed through inquiry cycle method supported by activities for CT skills gained higher scores than other groups of students. The result also showed that all three groups of students had satisfaction towards the instruction at a high level. Tongpan, Udom, and Tebnual (2009) compared 44 Prathomsuksa five students' CT abilities and science learning achievement before and after the students engaged in learning activities based on inquiry teaching method with questioning techniques. The result of the study showed significant increase of students' learning outcome at the end of the study. According to those research findings, it seems that different learning activities that students experience and deal with impact on students' learning and thinking abilities. Development of learning activities and training teachers to implement productively such activities related this area have become a heart of educational enterprises.

Although the result of educational standard assessments by ONESQA which is an external school institute revealed that students' CT abilities were improved gradually, ONESQA also suggested that some Thai schools still needed to develop significantly (ONESQA, 2003). The programs and workshops in Thailand for enhancing teachers' teaching practices intended to promote students' CT are generally quite short, and there is little in terms of follow up with respect to potential results. Because teachers' teaching practices have a significant impact on student achievement and thinking abilities (Roehring and Garrow, 2007) in Thailand, we are compelled to think about how to promote science teachers' competence in the promotion of critical thinking.

Consequently, a professional development appears to be a significant notion in progressing in teaching for CT. Loucks-Horseley, Love, Stiles, Mundry, and Hewson (2003) suggest that an effective way to develop a professional development might be to employ a variety of strategies combining together in the design and development of a professional development program. In promoting teachers' teaching practices, for example, teachers should consider, discuss and reflect on their own real teaching. They can indicate advantages and disadvantages in their classrooms, and then be able to provide suggestions about how to improve the classroom activities (Roehring and Garrow, 2007; Nielsen, Barry, and Staab, 2008). As professional development, however, teachers have special opportunities to interact and learn effectively through discussion and collaborative reflection (Krull, Oras, and Sisask, 2007; Taitelbaum, Mamlok-Naaman, Carmeli, and Hofstein, 2008). Teachers examine their own teaching practices leading to change and increase in the quality of their teaching practices, including knowledge of content, subject matter, and pedagogy (Borko, Jacobs, Eiteljorg, and Pittman, 2008).

Promoting teachers' understanding of and teaching practices for CT throughout a professional development in this study therefore, integrates a variety of professional development strategies altogether such like: teachers' backgrounds and teaching contexts, teachers' prior understanding of and teaching practices for CT, teachers' opportunities in discussions and reflections, and long-term engagement. This study is drawn upon interpretive research which applied the case study as a research design. Multiple qualitative methods are employed in order to gather data on teachers' understanding and teaching practices for CT including an open-ended questionnaire, classroom observations along with post-class interviews, semi-structured interviews with teachers, document reviews, and semi-structure interviews with students. In order to assess how the teachers change in their understanding of and teaching practices for CT as results of participating in the study, content analysis of a within-case and a cross-case analysis have been undertaken.

Research Objectives

The main purposes of this study are to enhance chemistry teachers' understanding of and teaching practices for CT through a designed professional development program. Preliminary, the study explores chemistry teachers' prior understanding of and teaching practices for CT. Then, the professional learning activities on teaching for critical thinking are developed, implemented, and evaluated the effectiveness of the PD program on teachers' teaching for CT. The study also aims to identify the effective features of the PD program which enhance the teaching for CT.

Research Questions

This study consists of two main research questions:

1. What is chemistry teachers' prior understanding of and teaching practices for critical thinking?

1.1 What are the chemistry teachers' understandings of teaching for critical thinking?

1.2 How do the chemistry teachers practice their own classroom activities in the context of teaching for critical thinking?

2. How does a designed professional development program affect on teachers' teaching for critical thinking?

2.1 How do teachers' teaching practices change as a result from the professional development program?

2.2 What factors constrain or facilitate teachers' teaching for critical thinking?

2.3 What are significant features of the professional development program enabling teachers' teaching for critical thinking?

Anticipated Outcomes

The results of the study will provide in-service professional developers or educators about effective professional development tools to enhance the teaching of critical thinking and to help them to design and develop a professional development program to enhance teachers' capacities in the promotion of teaching for CT.

Delimitation of the Study

Research Sites

This study was conducted in two extra large urban secondary schools under the Educational Service Area Office 1 of Nonthaburi Province, Thailand. The organizational education of the schools normally has set as two-semester system per year. The first semester has started from May to September, and the second semester has started from November to March. To the study, the researcher is studying in two upper secondary schools; Namsai Wittaya School and Tonnam Suksa School (Pseudonyms). According to report of external school quality assessment, students in these schools have been unsatisfactory in higher-ordered thinking abilities including

CT (ONESQA, 2003). In doing so, it is necessary to concern with teachers' understanding of and teaching practices in order to develop students' critical thinking.

Research Participants

With attempting to study in-depth understanding about chemistry teachers' understanding of and teaching practice for CT, it is suitable to deal with small participants who expressed to improve their confidence and competency in teaching for CT. The participants include three volunteer chemistry teachers from two different schools composing of Mr. Artid and Ms. Tawan from Namsai Wittaya School, and Ms. Ratree from Tonnam Suksa School. All three teachers have taught students in different grade levels and having different teaching experiences. Therefore, they are valuable participants to share and learn collaboratively with each other via engaging the professional development activities.

Chemistry Content

According to the National Science Curriculum Standards in Thailand (IPST, 2003), chemistry is set in sub-strand 3: matters and properties of matter. The participants in this study have taught Chemistry from grades 10-12. They work with different chemistry concepts depending on what topics are taught while the researcher observes the classrooms including chemical bond, chemical reaction, chemical equilibrium, state of matter, rates of chemical reaction, and acid-base reaction.

Definition of Terms

Teaching for Critical Thinking

Teaching for CT refers to both understanding of and teaching practices that enable teachers to promote their students' CT. The teaching for CT is characterized by teaching strategies employed to promote students becoming actively interaction and participation and expression of CT.

A Designed Professional Development Program

The PD program is to enhance purposively participant teachers' competencies in teaching for CT in Chemistry. The PD program is divided into two consecutive phases. Phase I is the designing the professional learning activities based upon the participant teachers' prior understanding of and teaching practices for CT and information from review of literature related to teaching for CT. Phase II is implementation and evaluation of the PD program on teaching for CT.

Organization of the Thesis

This thesis is organized consecutively into six chapters. The first chapter is to introduce the study; it aims to present the significance of the study, research objectives, research questions, anticipated outcome, and definition of terms. A great deal of information has been synthesized by reviewing a large sample of literature in chapter II including: education reform in Thailand, critical thinking, critical thinking and science teaching, teaching practices for critical thinking, and professional development of science teachers in the context of teaching for critical thinking. As well, research methodology and interpretive research is shown clearly in Chapter III. Chapter IV provides the findings for each three case. Chapter V presents common findings emerging by cross-case studies. The last chapter, Chapter VI, concludes my findings and answers research questions, and present some recommendations for further study.

CHAPTER II

REVIEW OF LITERATURE

Introduction

This chapter includes three major topics. The first topic is educational reform in Thailand which has been an area of the focus for the last decade. It attempts to move teaching and learning from traditional approach to alternative approaches, such as student-centered and constructivist approaches. Science teaching in Thai context also is advocated. The second topic is critical thinking that becomes a main goal of science teaching and learning. The topic includes definition of critical thinking, critical thinking and science education, and cultivating critical thinking through effective teaching science. The last topic of the chapter discusses professional development of science teachers in the context of teaching for CT. The final section summarizes the chapter as well provides guideline for features of the designed professional development program in the present study.

Educational Reform in Thailand

Transforming from an agriculture-based economy to an industrial or market-driven economy for last three decades, according to the Basic Education Curriculum B.E.2521 (adjusted B.E. 2533) of Thailand, educational reform in Thailand was called for strengthen students to be desirable citizens. The educational enterprises need to construct knowledge-based society where the students are involved in meaningful learning (ONEC, 1999). Citizens hence are required to experience in longer time in schooling year throughout student-centered instruction; schools are required to teach for procedural skills rather than content-driven instruction. According to learner-centered learning, the students are expected to develop in high cognitive abilities: thinking, practicing, and problem solving. Eventually, it is argued that, students will acquire more experience in the application of knowledge to real life situations and in their social development. With the rapidly changing of needs of economy and society in the Globalization era, education is seen as significant tool to driving nations to success; educational reform has become a way to affect this change.

As the critical concern for economic, political, cultural and social issues took the forefront in Thailand, a major movement of educational reform began seriously in 1997. Education is seen as a powerful tool for developing the quality of Thai people relying on the Constitution of the Kingdom of Thailand 1997 (Office of the Council of State, 2005). Consequently, the National Education Act 1999, the master legislation on the reform of Thai education, was declared. The Act is seen as a framework and guideline for Thai education endeavors to develop in the education system. The National Education Act 1999 aims to nurture potential students who are able to be competitive citizens and able to collaborate creatively in the current world circumstances (ONEC, 1999). The learning system should be organized with the students' best interests at heart, and enable them to develop their own pace within their individual interests and potential. Attention of the educational system, therefore, has turned towards the education of teaching for deep understanding as the great driving force for students' development of their abilities in the cognitive, affective, and psychomotor domains. Chapter 4, section 22 to section 30, of this document provides national education guidelines for instruction in Thailand. As mentioned in section 22 teaching-learning process should promote students in developing themselves to the best of their potential based on the principle that all learners are able to learn and develop themselves. Section 24 frames guidelines for educational institutions about organizing the learning process; educational institutions should not train students only in the thinking process but also provide learning activities drawn from learners' authentic experiences as well as enable learners to think critically (ONEC, 1999). Instructors are seen as a very vital factor in organizing teaching and learning activities; the educational institutions have to concern whether instructors are able to construct a meaningful classroom environment and instructional media properly. Educational institutions should assess student learning achievement using varieties of methods such as observations of their performances and results of testing. Specific to academic and professional substances of curricular in section 28, they should challenge the development of humans in knowledge, critical thinking, capability, and social responsibility. In doing so, it is essential for academic places to establish effective learning processes serving students' learning with deep understanding. The National Education Act of 1999 also outlines educational standards and quality assurance in chapter 6. Educational institutions themselves will establish internal and external quality assurance systems in order to assess the achievement of education. As well, each institution should be probed by external quality evaluation at least once in five years (ONEC, 1999). An important element of this Act is the discussion of teachers, faculty staff, and educational personnel. Educational institutions should provide the production of development of these groups in order to create an atmosphere of learning and understanding.

Being a government vision, the education will establish desirable citizens and occupations, the Basic Education Curriculum B.E. 2544 have been published with these goals in mind (Ministry of Education, 2001). This curriculum serves as the core curriculum for national education at the basic level. The curriculum also provides a framework of teaching and learning enrichment quality of citizens closely relate to educational goals to create lifelong learners. The curriculum aims to develop students' skills and processes such as: communication, science processes, and thinking skills in order to change societies from agricultural-based to market-driven societies. This curriculum functions as the national core curriculum providing flexible curriculum structure under specified learning standards. Schools, in practice, have to provide learning environment that facilitates learner progress in reaching well-informed and skilled-full persons. Schools requires a reform teaching and learning enterprises by cultivating alternative instructional approaches such like learner-centered and constructivist approached replacing traditional-didactic lecture approach (IPST, 2002). Correspondingly, schools will construct school-based curriculum concerning issues of community and local wisdom. In terms of instruction based on learner-centered learning, developments of students in content knowledge, thinking, ability, virtue, learning process, and responsibility are largely on the focus.

Science Instruction in Thai Context

With regard to the National Education Act 1999 that is a master document on the reform of Thai education, the Institute for the Promotion of Teaching Science and Technology [IPST] was established in order to research and develop effectiveness of teaching and learning science and mathematics in Thai context. Specific to science instruction in Thailand, there are a number of documents pertaining to science education at hand. Almost of such documents are concerned teaching and learning science typically relying on guideline and recommendation in the National Science Curriculum Standards [NSCS] B.E. 2544 by IPST (2002). The teaching of science, according to the NSCS, should accomplish the goal of developing students' capacities in these areas:

1) Understanding of the principles and theories in basic science
2) Understanding of the scope, nature and limitations of science
3) Acquiring knowledge and solving the problems in science and technology
4) Developing a thinking process, imagination, and abilities in solving a problem, managing data, communicating with each other, and making a decision.
5) Realizing the relationships between science, technology, humanity, and environment in terms of the influence and impact on each other
6) Applying the knowledge regarding science and technology for the benefits of their societies and daily lives
7) Having the attitudes, moral, ethics, and appreciations to utilize science and technology productively (IPST, 2002: 36).

In order to cultivate students' capabilities as above requirements, it is essential for science curriculum to set up effective activities targeting to promote students' meaningful learning as well as possessing scientific knowledge and process skills at the same time. The NSCS frames characteristics of instructional activities accordance with learner-centered approach in science teaching and learning as outlined below:

> They will undertake activities that help learners in developing reasoning, critical and creative thinking, analytical ability and skills in research and creating knowledge through investigation, systematic problem solving and decision making based on diverse data and verifiable evidences and skills in utilizing technology in data acquisition and management (IPST, 2002: 1-2).

Correspondingly, the foundation of science teaching and learning outlines one aim for developing students which is to enhance learners thinking processes and imagination, and ability to solve problems, make decisions, manage data, and communicate effectively (IPST, 2001). Science learning is divided into eight sub-strands; they are core basic science which all students are expected to learn. Following presents the subject matters of 8 principle sub-strands (IPST, 2002: 5):

Sub-strand 1: Living Things and Living Processes
Sub-strand 2: Life and Environment
Sub-strand 3: Matters and 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
Sub-strand 8: Nature of Science and Technology

Typically, school curriculum contains science subjects for students all grade levels. In elementary and lower secondary levels, students will be educated scientific knowledge, scientific skills, and scientific process based upon eight sub-strands through the same subjects. After that, for science classes are nurtured science in three particular areas: Biology, Chemistry, and Physics. For non-science class, the students are experienced in basic science knowledge and skills by enrolling Science subjects.

To Chemistry subject which is the focus of this study, its concepts have been located in science curriculum in upper secondary students up to higher education levels who decide to enroll in science program. This study focus on science content in sub-strand 3: matters and properties for fourth level students, grade 10-12 levels. The aims of this sub-strand are that students enable to understand on properties of matters, relationship between properties and structures and forces among particles, change of states of matters, formation of solution, and chemical reaction. In addition students should master in investigative process, scientific mind, and make positive applications of knowledge (IPST, 2001). So, grade 10-12 level students are expected their abilities before they complete learning standards that they have to be able to search for information discuss and explain about content subject matters what they are studying. They also are required to investigate and analyze data in experiments relevant to content. The most important expectation is that students should take advantage of chemistry knowledge by linking to everyday life (IPST, 2002).

Chemistry instruction activities emphasize on the developing students in scientific inquiry, collaborative learning, project-based and problem-based learning. Similarly, science education and chemistry instruction intend to promote students themselves to experience and think in complex and challenging ways if they are to make meaningful learning. Effective teaching on chemistry should be a process which engages student in CT, experimentation, and discovery. Learner-centered teaching and learning purposely incorporates higher-order thinking skills. It attempts to provide students opportunities to develop these skills via exploration, inquiry, and direct experience (Boddy, Watson, and Aubusson, 2003).

To accomplish the education reform of Thailand, in-service teachers are seen as an important factor provides classroom environments to advance students in their meaningful learning. With the intention of educational institutes for improving the teacher competencies instructionally, the Science and Technology Teacher Standards were produced by IPST in 2001. The main focus of this document is to provide frameworks and guidelines for educational institutes to prepare their own personnel. The teacher standards also will be criteria for assessing and enhancing teachers' instructional practices (IPST, 2001). This document provides three main aspects to assess science and technology teachers in their instruction; the three aspects include: knowledge, expression, and ability in their educational enterprise (IPST, 2001).

Beyond knowledge and understanding of the nature of science and technology, according to the fifth standard, it is essential for science and technology teachers to employ teaching methods pertaining to develop students in analytical and critical thinking whereas teaching should enable students in solving problems and process skills at the same time (IPST, 2001).

According to the above mentioned, the improvement of teachers' knowledge and skills is clearly important to result in students' learning. Therefore, the reform of Thai education should not only require students to improve their capabilities but should also enhance teachers to improve as well. In doing so, the development of science education in Thailand has given priority to professional development programs as one effective method for enhancing the teacher profession. Science teachers in particular need to develop themselves continuously in science knowledge and pedagogical knowledge to teach science effectively.

Many of Thai teachers still hold their teaching practices following a traditional approach that instructors transfer a body of knowledge to learners (Khaemmani, 2006). Even though they employ learning activities based on alternative approaches to students. Finally, students are hindered to reach to their best potential in learning. In providing learners with meaningful learning environments, schools should concentrate on learning materials, physical activities and thinking tasks to promote student learning potentially. Effective learning will occur while the learners themselves have opportunities to engage deeply with learning activities, and being active learners in the construction of their understanding about what the world is.

According to Pillay's study (2002), a report on education reform of Thailand, the study is concerned to introducing and implementing learner-centered teaching and learning approach to education of Thailand. Referring to a pilot project which used a school-based bottom-up model of instructional enterprise, there have been 253 schools involving teachers, students, and Research and Development (R and D) teams participated. The researcher revealed that many participants have difficulties with some issues of learner-centered approach. Teachers needed to change their beliefs about the nature of knowledge and how students learn; in this case teachers are still viewed as a body of knowledge which students will learn through a transmission process. Teachers needed to know how to encourage students to experiment, discover, and take risks. Some teachers feared that the students may break equipment; therefore they decide to pursue a lesson of lecturing or demonstrating rather doing science by engaging experimentation.

In addition, Isarena (2007) investigated Thai teachers' beliefs about learner-centered education as an effect of implementing Success for Life Thailand, a childhood education program at Kasetsart University, Thailand which emphasized practices of this learner-centered philosophy from 1999 to 2006. This study employed questionnaire about beliefs about leaner-centered approach and effects of implementing the approach on success for life Thailand with 600,000 teachers in Thailand. The findings revealed that 31.4% of the teachers applied learner-centered teaching below average whereas 28% practiced in levels of good and excellent. 38.7% of the teachers applied learner-centered teaching in their practice and tended to improve more in teaching a learner-centered approach. As well, the teachers held strong developmentally appropriate practice (DAP) beliefs in learner-centered teaching, however, their DAP belief in the study was stronger than their DAP practice regularly.

In summary, traditional instruction still appears dominant in Thailand. These ways of learning have resulted in short-term memorization (Pillay, 2002; Yutakom and Chaiso, 2007). To meet with the endeavor of education reform in Thailand under its new learner-centered philosophy, Thai teachers are now required to develop learner-centered teaching practices. Enhancing teachers' practice via professional development is one approach being pursued by the government to help develop students' skills, including CT skills.

Critical Thinking

This section of review is relevant to the body of literature about CT. It can be recognized that CT becomes a heart of education. The conceptualizing of CT is one of main goals fostered across curriculum (Facione, 1990; Bailin, Case, Coombs, and Daniels, 1999a). In order to provide effective instruction in the context of teaching for CT in chemistry, it is reasonable and necessary to acquire conceptualizing definition of critical thinking and linking teaching for CT to science classroom. Hence, this part of review concentrates on definition of critical thinking, critical thinking and science education, and cultivating critical thinking through effective teaching science.

Definition of Critical Thinking

In recent years, the actual meaning of CT is still controversial. With prevalent conceptions of what CT means, it has no precise definition (Bailin, 2002). However, CT is frequently conceptualized in term of procedures, processes, skills and practices (Bailin *et al.*, 1999a). It also is important to note that much of the literature uses overlapping of such terms in order to refer to CT. It tends to refer to as cognitive skills which are gradually developed by procedural practice (Bailin *et al.*, 1999a; Matchett, 2009). CT is also applied to a variety of different situations (Moore, 2004). CT is sometimes seen as a hierarchical form of cognitive skills. For example, a revision of Bloom’s taxonomy where categorizes cognitive process into 6 aspects from simple to more complicate verb form: remember, understand, apply, analyze, evaluate, and create consecutively. To this revised taxonomy, abilities to apply, analyze, evaluate, and create are involved in CT process (Krathwohl, 2002; Amer, 2006).

Critical thinking also is conceptualized as cognitive terms. CT can refer to thought of reflective, purposeful, reasoned, and goal-directed thinking concerning to make a decision, solve a problem, and evaluate an argument (Halpern, 1999; Couros, 2002; Moore, 2004; Willingham, 2007). It is necessary to think critically relying on available evidences to support truth and validity of reasoned position and action (Couros, 2002). Therefore, it represents rational, logical, reflective, and consequential evaluative thinking to decide what knowledge and information to accept or reject taking responsibility for one's decision (Zoller *et al*., 2000b). It can be said that CT involves inquiry, problem solving, decision making, and action requiring knowledge of disciplines dealing with interdisciplinary real life situations (Zoller *et al*., 2000b). Therefore, the heart of CT skills represents analyzing, interpreting, inferring, explaining, evaluating, monitoring and correcting application of one's own reasons and evidences (Facione, Facione, and Giancarlo, 2000).

In another view, CT is composed of three related domains of attitude, knowledge, and skills (Davson-Galle, 2004). For example, a critical thinker will be willing to inquire knowledge and meaning with acceptable supporting evidences. To this event, the critical thinker requires also knowledge to determine resources and use reasonable information to make a rational decision with evidences. In another words, CT concerns ability to use attitude and knowledge for applying and evaluating statements or situations (Watson and Glaser, 1964 cited in Sroymuk, 2004). In recent time, CT becomes an important tool in inquiry (Facione *et al*., 2000). The followings present three domains of critical thinking including: critical thinking as skills, critical thinking as processes, and critical thinking as dispositions.

Critical Thinking as Skills

To word of "skill", it can be indicated that CT can be developed via practice both separated and integrated subjects (Moore, 2004). There are many aspects representative of CT. CT, for instance classified by Lipman (Lipman cited in Ornstein and Hunkins, 2004), presented the distinct aspects of ordinary thought changing to critical thought: 1) guessing to estimating, 2) preferring to evaluating, 3) grouping to classifying, 4) believing to assuming, 5) inferring to inferring logically, 6) conceptualizing to grasping principles, 7) noting relationships to noting relationships among relationships, 8) supposing to hypothesizing, 9) offering opinions without reasons to offering opinions with reasons, and from 10) making judgments without criteria to making judgments criteria. Ennis (1985) also provides meaningful CT skills such as grasping the meaning of statements, judging assumptions in reasoning, and drawing conclusions. Paul and Elder (2002) proposed skills of CT as abilities to: raise crucial questions and problems, use criteria to meet well-reasoned conclusions, use language of disciplines to communicate with others, and relate what learned in subject to other subjects and to real human life.

Critical thinking skill is one among a set of related forms to higher-order thinking, for example, solving problems, making decisions, and creative thinking (Facione, 1990; Paul and Elder, 2007b). They sometimes present the complex relationship with each other. Watson and Glaser (1964 cited in IPST, 2001) have been divided conceptions of CT abilities into five aspects providing good understanding about CT skills as below.

- **Inference** means the ability to classify the possibility of predicting conclusions based on offered situations by using evidences and information in handy.

- **Recognition of assumptions** means the ability to identify or inform assumptions of basic information to consider further information and evidences.

- **Deductive reasoning** means the ability to make a decision that each conclusion resulted from exactly offered situations; if the conclusion being considered were false and if all premises of the argument were true.

- **Evaluation of an argument** means the ability to assess claims and arguments holding reasonably and containing agreements between arguments and reasons.

- **Interpretation of information** means the ability to categorize, decode, and clarify significant meanings relying on offered situations. It covers ability to understand and provide reasons for information, and then describe situations appropriately.

To assess student abilities in CT, there are productive instruments used for assessing CT skills. Ennis (1985), for example, developed Cornell Critical Thinking

Tests which presented a common feature of CT assessment. It had a series of subsets to measure skills of CT such as induction, deduction, and identification of assumptions. The California Critical Thinking Skills Test (CCTST) also, constructed by Facione in 1990 have five cores of CT skills including: analysis, inference, evaluation, deductive reasoning, and inductive reasoning. Following table presents list of CT skills and sub-skills based on the CCTST.

Table 2.1 Consensus List of Critical Thinking Cognitive Skills and Sub-Skills Based on the CCTST

Skill	Sub-skills	Skill	Sub-skills
Interpretation	Categorization Decoding significance Clarifying meaning	Inference	Querying evidence Conjecturing Alternatives Drawing conclusions
Analysis	Examining ideas Identifying arguments Analyzing arguments	Explanation	Stating results Justifying Procedures Presenting Arguments
Evaluation	Assessing claims Assessing arguments	Self-Regulation	Self-examination Self-correction

Source: Facione (1990)

Critical Thinking as Processes

One important reason, in fact, to provide CT as processes is that schools are able to engage their students in certain contents and skills across curriculum, such as abstract, analyze, classify, evaluate sequence, synthesize, and translate (Bailin *et al.*, 1999a). Processes of CT are described by many educators which the processes are concerned with solving problems with reflective thinking and reasoning (Bailin *et al.*, 1999a; Perkins and Murphy, 2007; Finn, 2011). A CT process typically requires the uses of vary cognitive skills. For example, it is composed a sequence of defining a problem, and considering and categorizing conditions of the problem, choosing significant information, identifying assumptions to use in solving the problem, and posing good hypothesis to test the answers for the problem (Sroymuk, 2004). Similarly, Paul (cited in Khaemmani, 2009) also pointed out that CT process comprises of 1) thinking to find ways for solving a problem or to gain knowledge, 2) identifying key questions of the problem what is a significant problem needed to solve or what is an important question requiring the answer first, 3) using information to make decision, and 4) relying on accurate and believable evidences, 5) using reasoning concept, law, theory, or principle to solve the problem, 6) hypothesizing leading to ways to reach the answers, and 7) applying knowledge and considering results of decisions.

Finn (2011) characterized CT processes into three sets of vary cognitive skills depending on their goals and objectives including: interpretative, evaluative, and metacognitive skills. Firstly, interpretation is to investigate how much we understand the argument as the focus of our thinking. Three steps are involved to interpretive an argument, including identifying the argument, identifying the relative reasons in hands for supporting the argument, and assessing the relative reasons and information for clarity. Secondly, evaluation is to examine how believable of an argument based on reasons provided. There are three steps in order to evaluate the argument, including examining the quality of inferences relying on reasons to a conclusion of the argument, examining the quality of various kinds of evidences, and judging the overall quality of the argument. The last of CT processes drew by Finn is Metacognitive skills. Metacognition refers to thinking about one's own thinking (Chatkup and Chuchart, 2001); it is to determine and evaluate the quality of thinking which is relevant to three steps: monitoring essences of thinking while interpreting the argument, checking biases and assumptions relevant to the argument, and assessing thinking strategies seeking to reasonable and productive evidences.

Furthermore, CT processes often relate to scientific process. It involves defining a problem, observing and choosing believable information, explaining, listening, and linking and comparing and contrasting some things, and assessing and applying conclusions (Khaemmani *et al.*, 2001). In science courses, students are presented to a scientific problem with alternative options and theories which ones to believe after a critical analysis (making a decision). Malamitsa *et al.* (2009) indicated that the students have learned science by experiencing in defining problems, designing strategies, collecting and interpreting data, developing arguments, evaluating solving problems, and drawing conclusions. A learning cycle of 5E inquiry learning also relates to CT process where students have learned to discover scientific knowledge and science process skills via sequent steps of engagement, exploration, explanation, extension, and evaluation (IPST, 2002; Buntod, Suksringam, and Singseevo, 2010). Students have a large number of opportunities to think critically by using reasoning, available and reliable resources based on such CT processes. They possibly become good in think critically when they need to solve a problem and make a decision.

Critical Thinking as Dispositions

Ennis and Paul appeared the first who considered CT as combination of both specific skills and dispositions, but Paul only stressed more on activities of the thinker than the thought itself. Paul stated that it is not enough to teach students only CT skills, but they have to be pleasure to use them and to have willingness of engaging in the effortful thinking process (Halpern, 1999). Paul and Elder (2002) provided foundational intellectual dispositions that define the traits of the disciplined thinker with several ideas for becoming a master student, for example understanding of requirements of each class, being an active learner via active reading, writing, speaking, and listening, being a good questioner and engaging in lectures and discussions, trying to practice thinking with exemplified by instructors, linking content to issues and practical situations in your life, looking at what learning skills you are not good and improving them. Positive dispositions toward something are expressed in person's habits and ways of acting (Facione *et al*., 2000).

Being a good critical thinker, a person must be able to reflect on reasons and evidences relevant to a decision. Students who have strong CT dispositions have typically a willingness to employ CT skills to make a decision or solve a problem whereas others who are good in CT skills but lack a CT dispositions might not involve CT into their practice (Facione *et al*., 2000; Zoller *et al*., 2000b). In doing so, developing students in CT is not the best perception by fostering isolated CT skills and CT dispositions, but rather challenging them into willingness to deal with arguments and particular problems together (Bailin, Case, Coombs, and Daniels, 1999b; Zoller *et al.*, 2000a). The critical thinker, characterized by Bailin *et al*. (1999b), hence is required to possess important attitudes and habits of mind such as respect for reasons and truth, respect for high-quality products and performances, respect for others in group, respect for legitimate intellectual authority, possessing an inquiring attitude, open-mindedness, fair-mindedness, independent-mindedness, and an intellectual work-ethic (Bailin *et al*., 1999a). Therefore, there is an interrelation between CT skills and CT disposition. One outstanding instrument is designed and utilized to examine students' CT dispersions as the California Critical Thinking Dispositions Inventory [CCTDI] (Facione *et al.*, 2000); dispositions examined toward CT are composed of seven subscales including:

- The truth-seeking scale (T-scale), it concerns attentiveness to seek the best knowledge in offered situations by such as asking questions, and inquiring answers.

- The open-mindedness scale (O-scale), it represents being open-minded and patient of different views even if those views are different from one's own views.

- The analyticity scale (A-scale), it emphasizes employing reasons and evidences in problematic situations.

- The systematicity scale (S-scale), it considers being in way of one's inquiry with organized, orderly, focused, and diligent.

- The CT self-confidence (C-scale), it examines being of one's own reasoning processes.

- The inquisitiveness scale (I-scale), it sees attempt to acquire knowledge and to learn explanations even if applying the knowledge is not apparent.

- The maturity scale (M-scale), it looks at being judicious in one's decision making.

Teaching science in Thailand purposes to develop students to think critically for all grade levels relying on infusion approach (IPST, 2001; Attachitvatin, 2009). In science classrooms, we typically viewed CT to be cultivated as both terms of skills and dispositions. There are studies concerning CT which define the meaning of CT in way of higher cognitive abilities. Kunjan (1999) defined CT as capacity of mental human which occurs explicit through thinking process rationally and reflectively in order to make a decision and conclusion based on scientific method. Similarly, CT is ability to think carefully relied on available and believable evidence and information in order to make a reasoned and logical conclusion and decision, and then extent such conclusion to application (Kaewkongdee, 2001; Sroymuk, 2004). As well, CT can refer to ability to reflect a reasonable decision on what to believe and what to do, including ability to provide reasons for argument. It can be seen, CT which is promoted in Thailand means ability to think carefully, analytically, and synthetically to make a decision and solving problem based on rationally available evidences, not emotion or guess.

In summary, CT holds many conceptions about what it is, most of them still meet in a common notion; it is higher-ordered thinking which refers to both procedural skills and dispositions. So, this study then clarifies CT as quality of thoughtfulness which represents deliberate, disciplined, reasonable, reflective, inquired, and responsible thought that a person uses to decide and assess the validity about the world. In this study, students' CT abilities will be not assessed directly, but what students' expressions during their classes, doing assignments, and interviews are valuable to support the results of the study relevant to teachers' development in understanding and teaching practices for CT as the results of teachers' participation in a PD program.

Critical Thinking and Science Education

Ability to think critically is fundamental and a core academic skill to a good education and to being an active and desirable citizen in the world as well (Moore, 2004). In part, this shift towards the promotion of CT in schools arose from the 1960s, when American students obtained low academic achievement in science for international test. This might imply that most of students are limited to bring their knowledge gained from classroom to novel and different situations and their daily life. Consequently, the important question to educators is whether or not the students have learnt "critical thinking" or "higher order thinking" (Reece, 2002; Zohar, 2004; University of Maryland University College [UMUC], 2006). As Moore (2004) mentioned, fundamental to an active citizen is the ability to think critically resulting to a great power tool for solving problems. It is a similarity of awareness of significant role of CT in classrooms. CT is helpful to promote students' productive learning outcome; in the same way, cognitive learning activities encourage students to developing in CT abilities (Pitagsalee *et al*., 2007; Buntod *et al*., 2010). It is important to cultivate CT into classrooms of school subjects. In addition, students should be encouraged to transfer their CT abilities from subject matter into a variety of novel and different situations in the real world (Khaemmani, 2009; Couros, 2002; Davies, 2006; Barak *et al.*, 2007)

Promoting CT in the present and the future within science education has been emphasized. Educators recognize the importance of CT that it is not only in studying but a technology based economy facing worldwide competition also. People typically utilize CT in two circumstances, to make a decision and to discuss or solve a problem. A desirable citizen is representative by being possesses CT and able to integrate information from a variety of sources to make profitable decisions (Alazzi, 2008). Educationally, a great endeavor of science education in last two decades has been to develop CT and higher-ordered thinking (Bailin, 2002; Couros, 2002; Paul, 2005; Willingham, 2007). Teaching for CT is seen as a productive tool which leads students into acquisition of meaningful learning (Paul, 2005). Thus teaching for CT is incorporated in across school subjects including science. Science instruction is asked to enabling students to better think critically, and teachers have been asked to organize more thinking skills-based classrooms (Halpern, 1999).

Is It Hard to Teach CT?

"How to teach best CT" is debatable (Moore, 2004; Alazzi, 2008). It is the nature of CT; it is complicated and difficult *per se* (van Gelder, 2004). Consequently, it is hard to be taught; however, it also is needed to be incorporate into classroom activities (Bailin, 2002; Moore, 2004: van Gelder, 2004; Willingham, 2007). We have no certain teaching strategies to develop learners in thinking critically. We cannot make a man think critically, but we can help the man to acquire the skills and dispositions to think critically (Bailin *et al*., 1999b; Couros, 2000; Paul, 2005). There had been, in somewhere, courses of typically stand-alone subjects that is orientated to develop students in "a set of CT abilities and CT dispositions to help students "to decide what to believe and what to do" (Ennis, 1985). Nonetheless, it is argued that neither CT should be integrated within ordinary school subjects (i.e. social studies, learning languages, mathematics, and science) nor CT subject should be isolated independently to teach. According to various terms of CT as skill, process, and disposition, the conceptualizing of CT is paid to both general skills and plenty kinds of thought particular to disciplines, it is reasonable to cultivated CT within standard school subjects based on "infusion approach" (Moore, 2004; Zohar and Schwartzer, 2005; Davies, 2006). This infusion approach acknowledges known as the importance of specific aspects of CT for particular school disciplines. Students typically are required to engage in deep on what topics they are learning; at the same time they are intensively utilizing principles of thinking to reflect on their learning (Zohar, 2004; Matchett, 2009). Therefore, teaching for CT accordance with the infusion approach is prevalent in current education (Reece, 2002; Moore, 2004; Davies, 2006). A great deal of reports still complains about students' illustration of poor performance in area of science and high-ordered thinking (Stillings and Wenk, 1999; Veal, 2004; Barak *et al.*, 2007; Willingham, 2007). Consequently, key question here is "why is CT so hard to teach and incorporate in standard school subjects?"

To teach for CT, it is necessary to know and think about the nature of CT. There are three issues seem to be important barriers leading to difficulty of teaching for CT. Firstly, and perhaps most important, CT is so hard *per se*. It refers to what called as higher-ordered abilities (Bailin, 2002; Davson-Galle, 2004; van Gelder, 2004). Most of people, for example of Kuhn's study in 1991, are poor in CT. Kuhn interviewed 160 research participants in order to determine their reasoning abilities to support their own opinion based on provided situations. The findings showed that they were difficult to express supporting their own opinion even though they already acquire basic skills of general reasoning and argumentation (Kuhn, 1991). Secondly, to be a good critical thinker, a man has to master and combine many cognitive abilities together. It also takes time to become good in difficult thing (van Gelder, 2004). Lastly, CT seems to be debated about its transferable (Moore, 2004; van Gelder, 2004; Willingham, 2007). It is seen, for example, even though students are taught the ways to solve a particular problem like one mathematical or scientific problem, they might face with failure in solving a similar problem to original problem. They cannot apply the ways of the solution into other situations. Hence, Willingham (2007) reminded us in hardly teaching for CT as below caption.

> …Critical thinking is not a set of skills that can be developed at any time, in any context. It is a type of thought that even 3-year-olds can engage in-and even trained scientists can fail in…
>
> …Teaching students to think critically probably lies in large part in enabling them to deploy the right type of thinking at the right time (Willingham, 2007).

The focus of above issues directs to the nature of CT leading to hardness of teaching for CT. Another focus, it is influencing also, is paid to ways how we has dealt with CT. According to the report of the Wingspread Conference Center in Racing, Wisconsin State held in 1984 where outstanding educators from many countries met and shared each thought in order to categorize ways to develop students' thinking abilities into three terms:

1. Teaching for thinking: It refers to teaching general school subjects in ways promote students' thinking at the same time.

2. Teaching of thinking: It refers to teaching that focuses on mental and brain process in order to understand about how being human develop their thinking. It is isolated thinking course.

3. Teaching about thinking: It refers to Metacognition which help a man understand thinking process and thinking about one' own thinking.

Although, it was reported by literature that is complicated and difficult to teach for CT, CT can be developed in a man through practices; practice always makes perfect is acceptable in the context of teaching for CT. Bailin *et al*. (1999b) recommended that practice to develop abilities in CT is not repetition of the same thing or problems, rather application of acquiring knowledge into similar or novel situations effectively. This recommendation of Bailin *et al*. might be implied that more practice and taking longer time in CT development seemed to promote practitioners in CT abilities. Finally, people can learn and apply such abilities into their professional lives (Finn, 2011). Nonetheless, some serious obstacles to success in teaching for CT are figured out such as 1) teachers lack of a substantive concept of CT, 2) unrecognizing their lack of a substantive concept of CT, instead believing in sufficiently understanding about CT, and already successfully teaching CT in their subjects, and 3) short-term strategies to reform instruction despite lecture and rote memorization (Paul, 2005). Though, it looks hard and difficult to incorporate CT into particular disciplines, it is a great challenge which leads us to be successful in educational enterprises. In this research study, the focus of teaching CT is based upon "teaching for thinking" which the study is specific to teaching for CT in Chemistry.

Cultivating Critical Thinking through Effective Teaching Science

With regard to awareness of the importance of CT in school learning and living in real world, major goals of science instruction are paid largely to not only scientific knowledge, scientific skills, and scientific attitudes, but CT and solving problems also (IPST, 2001). Teaching science also aims additionally students to reach scientific literacy and view science as a powerful and productive ways to answer what and how the world is. It is important to note that since the 1980s people in many countries were confronted with circumstances requiring literacy of scientific knowledge and technology (Weinberger and Zohar, 2000). The Office of Outcomes Assessment, University of Maryland University College (2006) reported that the increasing importance of CT is underlined by the "intensive information society" as well as poor performance in areas of science, mathematics, and problem solving among international students. Facilitating, finally, the development of CT becomes very important; CT is necessary to support life-long learning as well as it is applied across multiple disciplines (Zoller *et al*., 2000a; Khaemmani, 2009). Science teachers become one of key factors in success of teaching for CT in scientific disciplines; they are required competencies in designing and implementing effectively classroom activities in ways of encouraging students' CT. An effective science teacher therefore should be able to incorporate teaching science for CT. Students should be involved in a variety of cognitive learning activities and tasks. Those cognitive activities and tasks also require profitable implementation to support students' CT as much as possible.

Thinking about How to Generate a CT Classroom

Effective learning activities usually serve effective and meaningful experiences for learners. While a controversial issue on what is the best to teach for CT, productive classroom activities are represented by how much they are challenging students to think and engage in provided hands-on and minds-on activities actively (Watts *et al.*, 1997; Alazzi, 2008; Simpson and Courtney, 2008). The CT activities should provide student opportunities to express their opinions along with reasoning to support them as well as the activities have to support students to apply gained knowledge and skills into different situations (Kuhn, 1999; Barak *et al.*, 2007; Perkins and Murphy, 2007; Simpson and Courtney, 2008; Buntod *et al*., 2010). There are several classroom activities aiming to promote student learning and CT during learning science through inquires-based investigation, hands-on and minds-on activities, the use of effective and critical questions, small group discussions and team-based learning, linking knowledge from schools into real-world (Zohar and Dori, 2003; Hofstein, Shore, and Kipnis, 2004; Khan, 2007; Khaemmani *et al*., 2001; Matchett, 2009; Ketsing, 2010).

Israeli project named "Thinking in Science Classroom" (TSC), for good instance, aimed to encourage students' higher order thinking within science classrooms based on the infusion approach to teaching thinking (Weinberger and Zohar, 2000; Moore, 2004). The project involved a variety of science activities to engage students in solving scientific problems. One section of the project was designed and implemented in order to foster students in critical and scientific thinking via learning activities such as a) inquiry and CT skills learning activities, b) investigation of micro-worlds, c) learning activities designed to foster argumentation skills about bioethical dilemmas, d) open-ended inquiry learning activities, e) fostering question-posing capabilities through a case-based teaching/learning method (Weinberger and Zohar, 2000; Zohar and Dori, 2003). This section involved 21 seventh grade classes which were divided into 10 classes of comparison group (taught by traditional and following textbooks), and 11 classes of experimental group (taught by the designed learning activities). The findings from this section (also from other sections of the project) showed that students who experienced in the designed learning activities are greater successful than their counterpart in developing scientific learning achievement, high cognitive skills, and higher-ordered thinking including CT. According to the result from the project, it pointed to significant roles of learning activities provided for students.

Inquired-Based Science Classrooms

A heat of science instruction is focused on an inquiry-oriented teaching and learning approach as well as critical and scientific thinking is interrelated with each other (Bailin, 2002; IPST, 2002; Paul, 2005; Willingham, 2007; Malamitsa Kasoutas, and Kokkotas, 2009). This approach is value to develop students' capacities in thinking and solving problems (Khan, 2007; Ketsing, 2010). Lipman (1991 cited in Couros, 2002) also indicated cognitive skills as representative of CT which relate to scientific ability such as inquiry skills, reasoning skills, scientific thinking, organization of information, and translation. In addition, the promotion of teaching and learning science by doing inquired-based investigation required CT abilities such as using critical and logical thinking, formulating questions, seeking answers, analyzing information, solving problems, making decisions, communicating with each other, and testing reliability of information (Bailin, 2002).

Regarding to teaching science by inquiry, students are expected to use several inquired skills and to develop their thinking abilities such as: asking questions, identifying the problems, generating hypotheses, designing and conducting an experiment, using appropriate tools and techniques to gather data, observing phenomena, analyzing and interpreting data, thinking critically and logically about relationships between evidences and explanations, applying the result and making prediction, constructing and analyzing alternative explanations, and communicating scientific arguments (Bailin *et al.*, 1999b; Weinberger and Zohar, 2000; IPST, 2001; Zohar and Schwartzer, 2005; Pitagsalee *et al*., 2007; Malamitsa *et al.*, 2009). This presents that it has interrelated benefits between learning science and thinking critically. In the same word, scientific inquiry motivates typically students' thinking whereas thinking ability is needed when students are dealing with scientific problems and tasks. In doing so, instruction should emphasize the integration of CT ability into science curriculum. Science classrooms must provide learning activities requiring CT (IPST, 2001). Hofstein *et al.* (2005) found that promoting student practice inquiry skills through inquiry-type experiments in chemistry such as asking relevant questions, hypothesising, designing an experiment, interpreting results and drawing conclusion improved more amount number of student questions and more complicated questions.

Using inquiry cycle to promote students' CT in learning science becomes productive. It was studied by Pitagsalee *et al.* (2006). The researchers investigated the comparison of the effect of three different aspects of inquiry to teaching including inquiry cycle method, inquiry cycle method followed by activities for CT skills, and inquiry cycle interspersed with CT skills, the sample of this study included three classes of 121 Matthayomsuksa one students in Thailand; those students were selected purposive sampling to be subjects of the study. The study indicated that all of three groups of students were better in CT abilities after they experienced in provided learning activities, and they also appreciate learning by inquiry cycle model. Moreover, the researchers reported that students who were instructed through inquiry cycle method scored similar with those who were taught via inquiry cycle interspersed with CT skills-but earlier, it was suggested that inquiry requires CT by its very nature, but gained lower score than those who learnt with inquiry cycle model followed by activities for CT skills (Pitagsalee *et al*., 2007). Similar investigation, Tongvised (2001) examined effect of teaching and learning activities on Matthayomsuksa three students' CT process in science. Teaching and learning design involved four consecutive stages, plan, operation, observation and reflection. The finding revealed that students improved their score on content knowledge test requiring CT abilities. Productively, it was found that students themselves developed their CT through those teaching and learning activities such as identifying problem, raising question, posing hypothesis, gathering data, and assessing believable information. Buntod *et al.* (2010) also found a similar finding that a group of students who were taught by 5E-learning cycle with met cognitive techniques demonstrated significantly an increase of learning science achievement and CT skills more than another group of students who learned using the teacher's handbook approach. Therefore, it can be noticed that teaching science by inquiry was one teaching strategy which promoted students' capability in higher-order thinking including CT (Bailin, 2002; Khan, 2007).

Generating Effective Questions to Promote CT

Critical and productive questions are value being as a driving force of thinking; it also can offer effectively development in each field by generating tasks, expressing problems, and scoping issues whereas answering often is the end of thought or the beginning of further questions in order to provide opportunities to think and learn better (Slack, 1997; Stillings and Wenk, 1999; Wilson, 1999; Paul and Elder, 2002a; Hofstein *et al.*, 2004; Tongpan *et al*., 2009). Ability to ask appropriate questions is a basic skill of a critical thinker (Couros, 2002; Hofstein *et al.*, 2004). So, a good questioner in disciplines can learn well in the significant content of the disciplines. Science education therefore has given precedence to encourage students to pose appropriate questions. It was reported by investigations that ability to raise an effective question was able to develop the questioner in thinking critically as well (Tongpan *et al*., 2009). Tongpan *et al.* (2009) found that 5 grade students who learned through inquiry teaching with using questioning techniques gained significantly higher scores in scientific achievement and CT skills comparison between pre- and post- tests. In addition, Hofstein, Navon, Kipnis, and Mamlok-Naaman (2005) compared ability to ask meaningful and scientific questions in chemistry classrooms between students who were taught through the inquiry approach and those who were taught by a traditional laboratory-type. Learning activities of inquiry group involved open-ended type experiment. The researchers examined students' asking questions via observations doing experiment, and after they reading critically a scientific article. The findings portrayed students in inquiry group who had experience in asking questions during chemistry laboratory outperformed more and better questions comparing with their counterpart. These researches seemed to recommend science teachers to be aware of using words and questions in classroom practices. Teachers should be able to raise high cognitive questions to challenge students to think carefully and critically about the questions and answers to the questions. On the other hands, students should have opportunities to generate effective and scientific questions; these learning activities are fundamental to develop their CT (Slack, 1997; Hofstein *et al*., 2005).

Cooperative Learning Needed CT

Cooperative learning or group-processing succeed in the development of CT by facilitate learners in sharing a various ideas and different perspectives together; they finally tend to reach "consensus decision" (Matchett, 2009). Zohar and Dori (2003) also found effectiveness of the Jigsaw cooperative learning method on students' capability to pose questions via reading scientifically environmental problems, following by solving complex problems, posing questions, conducting critical group discussions, and writing creative titles and passages with regard to controversial issues. These classroom activities improved student performance significantly with respect to number of questions posed, question orientation, and question complexity. Moreover, it is representative of teaching and learning success by determining whether knowledge and skills cultivated in the classrooms can be transferred to new situations and real-world circumstances; a critical thinker can do (Matchett, 2009).

Key Issues Influencing Teaching for CT

Although, almost of people have common agreement of interrelation between CT and construction of understanding within disciplines, many teachers who lack of concept of CT do rarely immerse CT in their classroom activities. They lacked of connection between conception of CT and conception of what they are teaching (Paul, 2005). Gelder (2004) stated that through we agree that promoting students' CT is a main goal of education; research also revealed that students do not acquire such ability as much as they could and should. What should be element focused on?, In real practice, teachers always linked their familiar way of teaching, related to transition of knowledge, with novel teaching and learning approach. Teachers want students use intellectual abilities but they have no clear what intellectual abilities are; this makes student difficulty to learn with deep understanding and to develop thinking abilities (Watts *et al*., 1997; Zohar, 2004; Torff and Sessions, 2006; Alazzi, 2008). To solve this problem and develop students in CT abilities in productive ways, it is necessary to consider how to enhance teachers in their practice to instruction for CT.

Teachers' beliefs and knowledge on teaching for CT also play role as a significant issue that impacts on teaching and learning in the context of the promotion of students' CT. Teachers are a key factor in educational development; what teachers' beliefs and knowledge typically result into how they practice in their actual classrooms (Veal, 2004; Roehrig and Garrow, 2007; Torff and Warburton, 2005; Juntaraprasert, 2009). There are serious beliefs and knowledge held by science teachers that hinder teaching for CT in area of teaching science. For example, teachers believed that teaching for CT is effective for high achieving students, not appropriate low academic achievers (Zohar *et al*., 2001; Zohar, 2004; Torff and Warburton, 2005; Torff and Sessions 2006). It has evidence that high CT activities benefit for low academic achievers (Zohar and Dori, 2003). Therefore, it is necessary to offer all students entering to tasks requiring CT (Torff and Warburton, 2005). Also, instructional practices for emphasizing CT must be different from traditional instruction where offers low CT activities (Torff and Warburton, 2005). Teachers' teaching practices the use of high CT activities are needed in classroom in order to foster student CT ability. Van Gelder (2004) also pointed out the crucial reasons why it is so hard to teach CT are that CT is quite complicate teaching skill, and it requires basic skills such as general reasoning skill and argumentation to better in it, which many people are not good in these basic skills. The promotion of students' CT ability will be succeeded when students are encouraged in the right way and in the right time (Willingham, 2007); seriously, students were found their lack of the complex cognition to solve a problem (Wolcott, 2000). Moreover, effective critical thinkers need to practice frequently their critical thought. Students must engage in tasks challenging for CT, not only understand what CT is. Correctly, students should be encouraged their basic skills of thinking such as data searching methods, experts' opinion, and strategies for correctly solving highly structured tasks (Wolcott, 2000). In addition, these following basic skills can assist students to learn better in more complex skills including CT (Chatkup and Chuchart, 2001).

Asking question	Analyzing argument
Posing hypothesis	Identifying practical plan
Observing and making decision	Concluding relied on fact
Predicting according to logic	Defining meaning of term
Relating something with others	Assessing reliability of information

Problematic concerns, Paul (2005) stated that teachers might be not aware about importance of student's higher-ordered thinking as thought clearly, accurately, precisely, relevantly, or logically, rather they concerned only basic skills such as posing questions, and gathering relevant data. Of course, teachers, to motivate students think critically, must to understand what CT means first, it also is great that teachers are critical thinkers themselves.

The important essence of instruction in this field is teachers' knowledge of teaching for CT including subject matter knowledge and pedagogical content knowledge (Veal, 2004; Zohar and Schwartzer, 2005; Alazzi, 2008). In context of teaching for CT, subject matter refers to knowledge of what is CT and pedagogies of teaching CT (Weinberger and Zohar, 2000). Teachers are required to know a variety of thinking skills and thinking processes. In cognitive level, they should able to use thinking skills to solve a problem and to complete tasks. In metacognitive level, they need to acquire thinking about thinking. Teachers should describe their own thinking process and give the reason why they use that thinking process. Moreover, teachers have to know how to implement thinking curriculum, plan lessons for thinking, provide actively thinking activities, engage students intensively in tasks requiring thinking abilities, encourage students to use language of thinking, and evaluate students' thinking and learning. Teachers also need to change their own roles from telling of knowledge and fact to facilitating students' meaningful learning (Watts *et al*., 1997; Zohar, 2004; Finn, 2011).

This study sees the importance of teachers' understanding of teaching for CT in Chemistry which typically characterizes how they incorporate teaching practices for CT. In science, such as chemistry class, teaching for CT can involve inquiry-type laboratory, read scientific articles, problem-solving strategy, collaborative learning, and fostering student question asking. Those activities are useful to provide students opportunities in expressing their thought and sharing their ideas with others.

Professional Development for Science Teachers

Regarding to national education guideline indicated in National Education Act 1999 and amendments (The second National Education Act 2002) (ONEC, 2002), teaching and learning process in Thailand shall enable learners themselves at their own pace and to the best of their potentiality. Organizing learning experience also shall enable learners to think critically. The focus of educational reform is concerned to teachers' roles and their competencies. Teachers' teaching practices in their classrooms have largely affected on students' learning and achievement (Veal, 2004; Roehrig and

Garrow, 2007; Juntaraprasert, 2009). Therefore, differences in teacher practices can make differences in students learning outcomes. To meet those education reforms, teachers must to rearrange their roles from teacher-directed teaching to teacher-facilitated teaching; teachers shall be able to provide several learning experiences in order to facilitate student learning. Their competencies accordance with novel teaching and learning approach student-centered or constructivist teaching and learning approaches has been called. Teachers need to acquire the support of development of the profession of teachers (ONEC, 2002). In order to meet goals of the education reform, educational standards and quality assurance are necessary. In Thailand, the quality of educational schools is an examined continuous process by internal and external organization. This process requires annual reports for educational institutes in order to develop and strengthen in constant and sustainable teacher competencies.

In Thailand, almost of professional development activities for science teachers have been investigated and provided by IPST who takes responsible for developing science, mathematics, and technology teachers (IPST, 2001). Pillay (2002) reported, in general, that most of professional development activities prior to publishing Thai National Education Act 2002 has held on short and occasional of 2-3 days-courses or workshops to foster both pre-service and in-service teachers' improvement in teaching practices based upon educational reform. Those courses/workshops seemed to be following traditional teaching and learning approach. The courses/workshops provided teachers a huge amount of knowledge of content subjects and pedagogies by lecture-based learning. Teachers just sat and listen to lecturers or just watched demonstration of hands-on activities; it is not enough for teachers to apply knowledge based on such professional learning into their practice (Pillay, 2002; Puntumasen, 2004; Yutakom and Chaiso, 2007). They followed knowledge and teaching activities from the professional development courses/workshops without concerning appropriateness of contextual: students' background and prior knowledge, school context, and local context. Furthermore, such professional learning activities had no strategies to evaluate effectiveness of the activities on how much teachers incorporate their knowledge from the courses/workshops in their teaching; they might be ineffective to practice in ways of developing students' meaningful learning as a major goal of such courses/workshops (Pillay, 2002; Hanpipat, 2010). Therefore, it is time currently for reform strategies of professional development in Thailand.

Bell (1998) revealed that there are three aspects that recommended for science teacher development; personal, social and professional development. Personal development wants teachers to be aware of the need of professional development and acknowledge the need for new ideas and strategies in their classroom practice. Similarly, teachers can foster their social development by discussing and communicating with their colleagues and other teachers about what it means to teach science and to be a teacher of science (Juntaraprasert, 2009; Ketsing, 2010). The last aspect is professional development that appears fruitful to empower teacher competencies in personal and social development. It can strengthen teachers in their profession and supports them to implement the new ideas and strategies in practice for student learning better. Furthermore, teacher development requires teacher knowledge of science content, learner learning and difficulty, teaching strategies, and pedagogical content knowledge (Pillay, 2002; Loucks-Horseley *et al*., 2003; Faikhamta, 2007; Khaemmani, 2009).

To design virtually, a professional development tool, it is no actual conception which one strategy is the best option to implement; it is typically based upon different contexts, different goals, and different circumstances. The important consideration is how to fit such strategies for teachers' sustainable learning and achieving goals. It is essential that each strategy requires specific elements to implement. Frequently, a combination of professional development strategies has been employed. In order to meet typical four desired learning outcomes, Loucks-Horseley *et al.* (2003) stated driving professional development designs in areas of 1) increasing science and mathematics teachers content knowledge, 2) increasing teachers pedagogical content knowledge, 3) building a professional learning community, and 4) developing leadership.

It is important for designers to understand about context of relevant to professional development such as background of teachers, background of students, and factors affecting professional learning. Loucks-Horseley *et al*. (2003) recommended a framework to organize a PD program for in-service mathematics and science teachers. This framework could be a good element for novel professional developers because it was evolved by skillful professional designers and drew upon research, literature, and practice. It has six steps of the framework including:

1. Committing to vision and standards,
2. Analyzing learners and learning and relevant contexts,
3. Raising goals of developing profession,
4. Planning strategies,
5. Implementing professional development tool, and then
6. Evaluating effectiveness of the tool.

The feedbacks, then, from evaluation of the tool provide further information to improve or reorganize each step of the tool for more effectively. In real practice for designing a program for the development of a science teacher profession, professional developers need to understand conceptions of learners and learning, teachers and teaching, the nature of science, professional development, and process of changing. Moreover, they need to gain knowledge about students' learning outcome, teacher needs, curriculum, instruction, assessment practice, available learning resources, and national and local policies.

Professional Development of Science Teachers in Teaching for CT

A great endeavor of education has cultivated CT across curriculum everywhere in the world (Lang, 2006). An effective science teacher should be able to incorporate science teaching for CT. Therefore, current study in which attempt to promote chemistry teachers' teaching practices pertaining to promote students' CT ability through a professional development program. It is important to study and review about means and strategies done by prior researchers about factors influencing teacher development in this research area. Themes are concerned including teachers' beliefs and knowledge about teaching for thinking; in particular CT, issues affecting teachers' teaching practices for CT, and characteristics of courses or programs enhancing teachers' teaching practices for CT. These findings serve as basis information to develop a program for teacher profession. This program is designed by means of several activities from professional development strategies in order to assist teacher learning as much as they could do best.

There are several professional learning strategies that assist teachers better in understanding and teaching practices in the context of teaching for CT. It is noticed that teachers' background and their prior understanding of teaching for CT is significant information in order to design professional learning activities (Zohar and Schwartzer, 2005; Punbo *et al.*, in press). Teachers' beliefs and knowledge usually affect how they learn through a provided professional development program or course. At the same time, those beliefs and knowledge characterizes mostly their application gained knowledge from the program or the course into actual classroom practice (Zohar and Dori, 2003; Roehring and Garrow, 2007; Juntaraprasert, 2009).

A professional development course or program enhancing teachers' teaching practices for the promotion of students' CT should be designed delicately. The professional development program should make sure that teachers will acquire better what CT is; it is fruitful if teachers gain abilities to provide a variety of teaching strategies in order to encourage students to cope with tasks requiring CT (Barak *et al.*, 2007). Teachers must to think how to develop students' CT while they are designing lesson plan, teaching material, and conducting their classes. Torff and Warburton (2005) recommended means to begin with development profession in this field including 1) encouraging teachers to analyze case studies of lesson plan in order to examine advantages and disadvantages of high- and low- CT activities for different background students, 2) providing effective models of CT activities to teachers, then allowing them to analyze such models, 3) allowing teachers participating in design curriculum, instruction, and assessment in order that use of high CT activities, and 4) allowing teachers to examine CT-based assessment procedures leads teachers use of CT tasks inequitably.

It is important to know teachers' beliefs and attitude toward teaching for thinking prior to design professional development program. One effective way applied is interview. Zohar *et al*. (2001) studied patterns of teachers' beliefs regarding teaching for higher order thinking with low-achieving students. The researchers employed semi-structured interview to examine teachers' beliefs about teaching for thinking. Issues to ask the teachers composed of two pasts, a) asking about teachers' options either letting students learn concept via solving problem or applying transmission of knowledge approach to teach students, and b) asking teachers' beliefs about their own teaching practice. The research results revealed similar findings with other studies. Although, 70% of teachers mentioned that CT-based learning was better than traditional instruction because it serves students deeper understanding of concepts and longer memory, they viewed that teaching methods such as inquiry and solving problem which require higher order thinking were appropriate with high-achieving students, not for low-academic achievers. They saw that thinking activities might bring frustration to those students. Therefore, teachers often avoid preparing thinking tasks for such students, but they would encourage students by asking them questions. To survey teachers' pedagogical knowledge concerning teaching for CT, Zohar and Schwartzer (2005) investigated science teachers in Israel. They examined teachers in four different topics. First, they explored teachers' attitude toward allowing students' independent thinking and solving problem versus teaching emphasizing covering content. Second, the topic is of teachers' beliefs about ways to treat students' wrong answers. Third, exploring is teachers' attitude about teaching higher-order thinking to low academic achievers. The last one is teachers' attitude about the role of cognitive conflict in learning. This questionnaire was completed by 150 science teachers including 90 high school teachers from 30 biology; physics; and chemistry teachers each, and 60 junior high school science teachers. The research found that biology teachers scored higher than physics and chemistry ones. The researchers supported that teaching biology in Israeli has focused on inquiry approach for 30 years ago, at that same time teaching physics and chemistry has applied more traditional instruction. This situation might lead biology teachers to do better in the questionnaire. It is supported that the matriculation examinations at high schools requiring coverage of content largely convey the teachers to teach focusing on subject matter more than thinking skills. This event resulted in higher score of junior science teachers than high school science teachers. The finding also revealed that teachers who have less teaching experience gained higher score than those who have more experience in teaching. This result is described; it is possible that novel instruction focus on construction of knowledge and inquiry has effect to novel teachers to gain more points. In another word, more teaching experience would get fewer score on pedagogical knowledge to teach for higher order thinking.

Issues influencing teaching for CT were investigated by Torff and Sessions (2006). They examined specific issues influencing teachers' pedagogical preference to use CT activities for low-achieving students. Firstly, the researchers interviewed 20 social studies teachers such questions about effectiveness of provided activities for teaching low-achievers, factors influencing teachers' decision to use or avoid such activities with low-achievers, and appropriateness of such activities more for low-achievers than those who gained high academic achieving. Findings displayed eleven factors affecting teachers' decision in whether or not they would use CT tasks; the factors included classroom management, assessment, high-stake tests, administrators, colleagues, parents, students' level of ability, students' level of motivation, students' level of prior knowledge, nature of subject, and time constraints. Then the researchers surveyed teachers' pedagogical preference based upon such issues influencing the use of CT activities with 120 social studies teachers. They found that teachers preferred to use high-level CT activities, associated with influences of high-stakes tests, administrators, and subject whereas issues about students' prior knowledge, motivation, and ability, time constraints, parents, and colleagues led teachers to use low-CT activities. Interestingly, classroom management and assessment did not affect teachers' decision to use both low- and high CT activities. Studying of Punbo *et al.* (in press) also supported the findings of Torff and Sessions. The researchers examined Thai chemistry teachers' teaching for CT. The findings revealed the factors that affected the teachers in teaching for CT including: the limitation of time, the teachers' knowledge in teaching for CT, the lack of chemicals and science apparatus, and teaching based subject matter for national examination.

Wolcott (2000) offered guidance of designing assignments and conducting classroom discussions to foster student CT through open-ended problems in business accounting class. Framework of assignment involved four consecutive sections. First, identifying the nature of open-ended problems is to let student understand why some problems never have one correct answer, at the same time students indicate the major factors or limitations obstructing the best solution. This section activity might be cases or readings appearing expert disagreement on the best solution, classroom discussions to generate list of aspects of problem, investigation of range of plausible solutions from experts or literature. Second, framing an open-ended problem is to identify evidences in order to examine problem from several perspectives, and then organize distinct perspectives to make qualitative interpretation of evidences. Classroom activities could interpreting and evaluating quality of different evidences, and providing students developing framework or concept map for organizing information and exploring the complexities around the problem. Third, resolving an open-ended problem offers the students to choose effective solutions by using reasons and evidences to support assumptions and conclusions about viable solutions. Learning activities in this section might involve presenting students frameworks to evaluate effective solutions; and ask students how they use principles and frameworks to evaluate the solutions. Fourth, re-addressing an open-ended problem provides students to recognize important limitations of solutions and employ inquiry process to get better solutions. Learning activity might foster students to describe limitations and conditions under each solution following by gathering new necessitate information.

Weinberger and Zohar (2000) have characterized course structure of professional development to enhance teachers' ability in teaching for higher-order thinking. That course should include sections of mini lectures and class discussions, active practice, and reflective practice. Therefore, in case of CT, professional development might consist of a) lectures for several general theoretical issues regarding to teaching for CT such as conception of CT, importance of integration of CT into science lesson, development of CT strategies, and assessment of CT; b) teachers' engaging actively with a variety of tasks requiring CT to solve a problem, in this way teachers act as they are learners. So, they learn what difficulty faced by the students, then they will think how to instruct their students; c) by reflection, teachers have opportunities to think aloud and share their thought with others; this allows them to analyze their thinking, and learn how to examine students' thinking as well. Individually written reflections also help to monitor teachers' changing and progression in their teaching practice. According this structure of course, participants revealed that they have much awareness of their own thinking process, and it improves their capabilities to teach for thinking.

Reflection is one effective way to change teachers' beliefs (Torff and Warburton, 2005; Zohar and Schwartzer, 2005; Krull *et al*., 2007; Nielsen *et al*., 2008; Juntaraprasert, 2009; Hanpipat, 2010; Ketsing, 2010). Reflecting might take place during classroom conversations, written journals, and portfolios. Moreover, interaction among action, observation, and evaluation during reflection motivate teacher awareness use of high CT tasks, and then develop them into classroom practice eventually. It might be clear that it has the effect on teacher purposely and persistently to practice for the promotion of higher-order thinking and CT (Zohar and Schwartzer, 2005; Barak *et al*., 2007). In addition, the study found that teaching strategies to promote students' thinking were characterized as, for example, linking what learned in classes with everyday life, emphasizing inquiry-orientated learning in group which motivated students in cooperative learning, encouraging open-ended class discussion situated by concepts or problems fostering students present their own solutions, posing open-ended questions, and encouraging students asking questions.

To develop teachers' teaching pedagogical knowledge of teaching for thinking, Zohar and Schwartzer (2005) implemented professional development course of three consecutive sections for a year. Their participants were 14 science teachers in Israeli whose attention paid on how to develop students' thinking. At first section of this course, teachers were required to solve problems through active learning activities by individuals and small group learning; they acted as if they were students. Then, teachers would watch videos displaying students' engagement the same activities teachers did. The teachers then discussed about students' difficulties and means to treat those difficulties. This section provided teachers some theoretical lectures of instruction for thinking; they also were asked to write reflection according to thinking tasks based on questions provided. Second section of the course included reflecting and discussing about teachers' written reflections from section one. The teachers then would design active thinking tasks and lessons. This way would strengthen teachers' understanding and teaching practice for thinking. The teachers also had opportunities to try out their lessons designed within their own classrooms, and then wrote reflections based upon their own teaching. Section 3 was conducted as the same way as section 2, but three months later. The results from classroom observations whereas teachers were trying out their designed lessons were very productive. The teachers applied thinking tasks more than early lessons. They also asked plenty of complicate questions requiring thinking and longer answers whereas asking questions for recall of information and comprehension has largely decreased. Successfully, the finding from late classroom observations displayed a variety of students' thinking. Students showed additional thinking strategies in late observations as CT such as forming definition, identifying relevant information for solving problems, identifying assumptions, sampling, constructing arguments, searching for factors to consider during discussion of problem, and asking question. Students were asked more frequent to deal with metacognitive discussions during lessons such as indicating their own thinking strategies applied, reflecting and explaining their mistake along with suggesting means to prevent such problems. At the end of teachers' course, however, there were not many teachers who were able to lead metacognitive discussion in their classrooms. The researchers found that teachers usually rejected immediately students' wrong responses in early observations while in late observations many teachers improved various strategies to encourage students' thinking when the students presented wrong responses such as generating a cognitive conflict, generating simpler, but similar questions. Moreover, the teachers said more frequently number of thinking words such as thinking, justifying, and making conclusion.

Lang (2006) suggests the DASK Model (Disposition, Attitude, Skill, and Knowledge) as the underpinning framework for the development of the cognitive infusion module in order to enhance pre-service teachers on CT skills and CT dispositions. Conceptualizing, these four components of the model have interrelation each other. This DASK Model attempts to integrate both the theoretical and practical dimensions of teaching thinking. The teachers also will be supported their classroom practices in order to promote students' CT effectively even if the teachers themselves have possessed CT skills and dispositions. The DASK Model depicted as below.

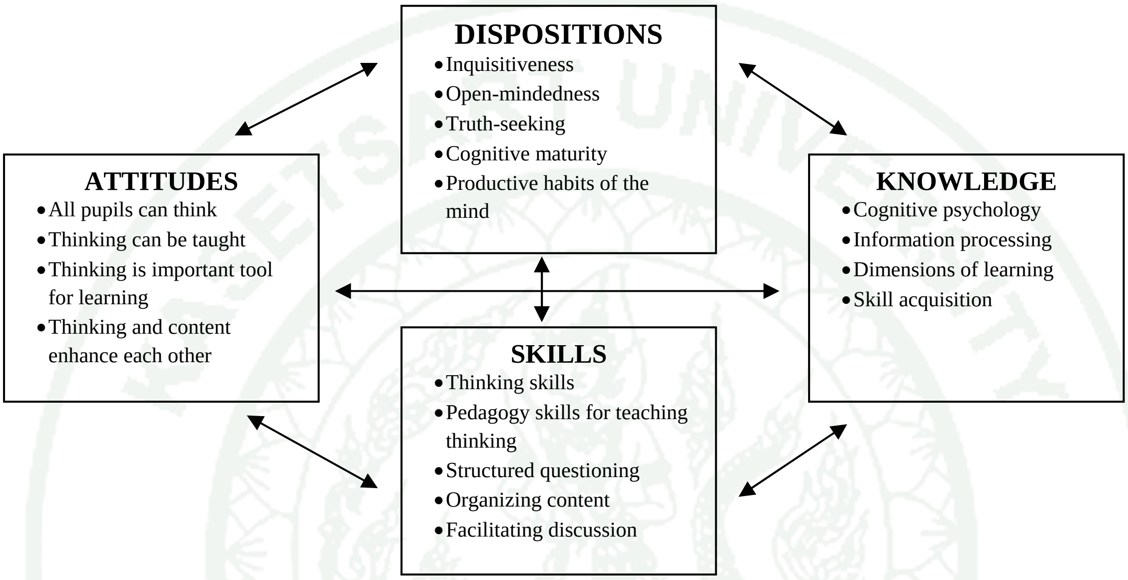

Figure 2.1 Components of the DASK Model

Source: Lang (2006)

Puntumasen (2004) suggested effective principles in order to develop sustainable in-service teacher profession in their teaching practice accordance with alternative teaching and learning approaches in Thailand. The effective in-service teacher development courses or programs shall involve such like: 1) a real situation and needs of teachers and school, 2) holding at natural school context or community, 3) promoting teachers' competencies by expertise and experienced leaders of learning reform, 4) willingness of participating teachers in development of their own profession, 5) collaborative working and learning between participating teachers and professional developers or researchers, 6) utilizing several professional learning methods, materials, and activities, 7) providing opportunities for discussion and reflection based on each rich understanding and teaching experiences, 8) implementing steps of planning, doing, checking, and reflecting consecutively, 9) evaluating professional learning outcomes relying on teachers' change in practice and students' achievement, and 10) holding on a regular activity of teachers that aims to meet quality and standards. These features of professional development courses provide a value to support sustainable teaching competencies of teachers.

Summary

In summary, designing a professional development program to enhance teachers' teaching practice for CT requires understanding of context of the study. Teachers' understanding and beliefs about teaching for CT plays role as important basic information as well as how teachers' teaching practice in currently is. It is important to persuade teachers having positive beliefs about teaching for thinking. Introduction of benefits of CT and conceptual meaning of CT might be a good way in order to encourage teachers' attempt to teach for CT. Characteristics of the professional development program to enhance teachers' teaching practice should involve key elements of many professional strategies together. According to this literature review consist of providing teachers' opportunities to engage in learning activities as if they are students, offers teacher understanding better what are student difficulties during participating in lessons, and teachers could find means how to assist and facilitate the student to learn meaningfully. So, the teachers improve their own understanding and teaching practice. Collaborating provides the teachers better ideas and options in their teaching practice. Discussions and reflections collaboratively on classroom activities provide the teachers how to plan learning activities, how to conduct their own classroom, and how to assess the student's learning outcome both products and processes based on individual progression and criteria. Therefore, the professional development program in this current search study would be designed through a combination of many aspects of professional learning that emphasize on collaboration, discussion, and reflection. Features of the professional development program would be detailed in-depth in Chapter III.

CHAPTER III

RESEARCH METHODOLOGY

Introduction

This chapter addresses the research methodology utilized Thai chemistry teachers' prior understanding of and teaching practices for CT, and then assesses the results of the PD program on CT. These results respond to two main research questions: 1) what is chemistry teachers' prior understanding of and teaching practices for CT? and 2) how does the PD program affect on teachers' understanding of and teaching practices for CT? Interpretive research guides the methodology for this research. Case study research and a cross-case analysis have been undertaken to respond to the research questions. Multiple qualitative methods are employed in order to gather data on teachers' understanding of and teaching practices for CT. Content analysis is the main way to analyze and answer the thesis argument how the program enhances chemistry teachers' understanding of and teaching practices for CT.

Methodological Framework

Qualitative Research

While researchers try to adopt properly theoretical perspective along with context of their research argument, qualitative researchers, in particular, have been challenged to construction of deep understanding about experiencing research participants based on their own context as the natural setting in a reality of the complex phenomena influenced by several interconnecting factors (Andrade, 2009). This type of research provides "thick description of phenomena" in order to understand and answer "how and why" research questions. The researchers naturally do not manipulate or try to set the research environment (Lincoln and Guba, 1985) since they believe that realities cannot be understood in isolation from their contexts; the individuals interact with environments such as professional learning program, classroom, school, community, colleagues, and so forth. To answer each qualitative research question, the researcher uses multiple data from multiple methods of collecting data such as questionnaire, interview, observation, and document analysis. Data is paid large attention to detail via words, events, and narrative, not number. Qualitative findings are generally presented in everyday language and often incorporate participants' own words to describe a phenomenon. The qualitative researchers play key role in data analysis and make a conclusion based upon theoretical perspective. They always generate themes or categorizations of data based upon multiple resources of evidences in rich and full description.

Interpretive Methodology

Interpretive research assists the researcher to address and describe reasonably what happens in classrooms concerning its own culture. In order to understand deeply about teacher classroom practices, according to qualitative research the researcher must form relationship with the teachers and gain knowledge about the culture and context of study which is an important tool for qualitative research. Classroom events present natural and dynamic phenomena where people practice based upon their own meaning (McCutcheon and Jung, 1990). Interpretive researchers need to feel familiar with contextual environments of study such as curriculum goals, teacher capability, teacher need, student need and interest for getting deep information. Therefore, the current study is concerned about a phenomenological perspective about how knowledge is generated and accepted. Interpretive researchers themselves are the primary research instruments in both data collection and data analysis (Lincoln and Guba, 1985; Merriam, 2009). The researchers need to get close with the whole data resources in order to collect and observe, and then take notes about what is seen. Building rapport and close relationships with participants is one necessary responsibility of the researchers. In addition, the researchers themselves are required to analyze and interpret the meaning of what happens in complex situations. Therefore, interpretive researchers are the essential tool to provide quality of the study. Knowledge claims informed from interpretive qualitative research emphasize knowledge on social interaction between people and people, and people and environment that serves as a way to construct meaning. Constructivist learning plays a theoretical role as to how people and teachers learn and change their knowledge and practices in qualitative research. People construct knowledge in mind of individual. Construction of meaning therefore is related to an individual's prior knowledge and experience as well as interaction with each other and their environment. At the same time, the researcher learns how teachers learn or construct their knowledge by interaction in person with teachers in order to encourage participant expression of their experiences, and then interprets the acquired notion to define the meaning of such notions.

In this research, the researcher used cross-case study as the guideline of the processes and procedures. A multiple cross case study approach seeks to discover the nature of the case, background of the case, physical and cultural context including what is general and what is particular among cases, as well as comparing what the differences are. The case researchers or data gatherers will concentrate largely on each case as if it is the only one in order to understand specific cases. They also need to generate the case features, and then figure out the case for others to see. Frequently, interpretive research involves a group of teachers or staff development sessions. More often, selection of cases from the group is practiced for in depth study by experiencing a particular context and situation. Case studies provide a unique example of real people in real situations; they help readers understand better about ideas, theories or principles (Cohen, Manion, and Morrison, 2000). In addition, case study attempts to describe insight naturally and particularly phenomena with rich and thick description (Denscombe, 1998; Freebody, 2003; Merriam, 2009) which it is necessary to enable readers to understand the phenomena under study (Faikhamta, 2007).

Research Design

This research applied case studies as a research design in which employed generally in educational research. While the case study is varies in definition as a category of research methods, methodologies, and designs, employing of the case study is helpful to discover the essence of the case in which locating the specific unit of analysis (VanWynsberghe and Samia, 2007). The case study also frames systematic ways for gathering, analyzing, and interpreting in-depth information in order to construct understanding based on naturally individual cases (Patton, 1990). Yin (2003) defined the case study as a method to collect data from multiple sources i.e. interviews, observations, and documents. VanWynsberghe and Samia (2007) provides a prototype view of case study including seven common features: 1) calling for a small number of cases in order to gain an intensive and in-depth focus on the specific unit of analysis, 2) providing a largely detail to conceptualize a sense of being there, 3) studying in natural and complex settings with less/no manipulating or controlling by researcher, 4) providing a detailed description of specific boundary by place and time to structure of interest, 5) generating working hypothesis and learn based on what appear during gathering and analyzing data, 6) utilizing multiple data sources facilitating triangulation and offers findings, and 7) enriching a readers' understanding of situations and phenomena relying upon interrelated factors in contextual study. With a small number of the cases, the study is not for predictions and generalizations (VanWynsberghe and Khan, 2007).

Interpretive researchers collect data by means of combining several data sources in order to define meaning about what is going on. They usually act as the primary research instrument to collect intensively abstract data such as view, understanding, thought, biography, interrelation between abstract data and environment, and so on. Faikhamta (2007) mentioned that the researchers prefer to analyze data employing an inductive strategy in order to generate conception, hypotheses or theory rather than to test theory. Researchers employ several methods to gather data concerning teachers' teaching practices for CT in their classrooms, such as: questionnaire, audio-taped and video-taped classroom observations, teachers' reflection on classroom incident, a variety of written material, interview, and so on (Weinberger and Zohar, 2000; Krull *et al*., 2007; Nielsen *et al*., 2008).

It is necessary to be concerned about the data analysis of interpretive research. Generally, raw data gathered from interpretive research presents a huge array of data and comes from a variety of data sources. The raw data itself is difficult to understand. Therefore, analysis of data represents the process to make meaning or provide information from the data. The process of data analysis involves organizing, coding, categorizing, reducing, and interpreting the meaning of the data (Patton, 1990; Merriam, 2009). Most interpretive researchers prefer to employ inductive analysis to categorize and generate knowledge claims and theories in which the theories will be grounded in data from particular contexts (Lincoln and Guba, 1985). For case studies, researchers always analyze data by using all the information of each case together. In multiple cross case studies, the researcher analyzes data within-case, and then makes data analysis among cases. The findings of a cross-case analysis generate categories, themes, or typologies that cover all the cases (Faikhamta, 2007).

The current research design involved gathering data by two main phases consecutively in order to address how a professional development program assisted chemistry teachers who participated in the study to improve their understanding of and teaching practice for CT. Utilizing of multiple qualitative data sources/methods was carried out: teachers' open-ended questionnaire, semi-structured interviews, classroom observations, workshop, group meeting, reflective journal, and document analysis. Interpretively data analysis is used in order to assess the effectiveness of the program and to see how the program influences teachers' understanding of and teaching practices for critical thinking during participation in the research study.

Table 3.1 The Relation between the Research Questions and Data Sources

Research question	Data source	Data obtained	Analysis
What is chemistry teachers' prior understanding of and teaching practices for CT?	Open-ended questionnaire	Teachers' understanding of teaching for CT, ones' own teaching for promoting students' CT	Transcribing classroom observations and interviews then identify obtained data into categorizing of teachers' understanding of and teaching practices for CT based on essential pedagogical development of teaching for CT in Table 3.3.
	Classroom observations with post-class interviews	Ways of teachers conducting their classrooms in the context of teaching for CT and examining teachers' perceptions about their lesson.	
	Semi-structured interviews with teachers (initial interview)	Teachers' understanding of teaching for CT and their reflection on their own teaching, factors influencing teaching for CT, and teachers' needs related to teaching for CT.	
	Document analysis related to teaching	Level of cognitive tasks provided and teachers' planning lessons.	Coding on pieces of tasks appeared complicate and requiring students' CT, and underlining suppose of teachers' ways to conduct lessons.

Table 3.1 (Continued)

Research question	Data source	Data obtained	Analysis
How does the PD program affect on teachers' teaching for CT?	Workshop on teaching for CT	Teachers' understanding of teaching for CT, ways that teachers suppose to teach, and teachers' lesson plans	Transcribing teachers' dealing with workshop activities, and categorizing teachers' reflection on teaching for CT.
	Classroom observations with post-class interviews	Teachers' changes in their teaching practices, and their perceptions about their changes in teaching for CT.	Coding ways to conduct lessons of the teachers, what their face during teaching based on teaching for CT, and coding teachers' understanding of and teaching practices based on teaching for CT.
	Group meetings	Teachers' lesson plans and actual classrooms based on teaching for CT.	
	Semi-structured interviews with teachers (final interview)	What teachers had learned and what their opinions about their development in teaching for CT.	
	Semi-structured interviews with students	Student attitude to Chemistry subject and their teachers' teaching	Transcribing interviews, then categorizing student attitude

Table 3.1 (Continued)

Research question	Data source	Data obtained	Analysis
	Reflective Journals	What teachers learned through their own teaching based on knowledge from the PD program	Categorizing teachers' perception about their learning and changes in teaching for CT
	Document Analysis Related to Teaching	Level of cognitive tasks that teachers provided and planned lessons.	Coding on pieces of tasks appeared complicate and requiring students' CT, and underlining suppose of teachers' ways to conduct lessons.

Context of the Study

School Context

This study was conducted in two extra large urban secondary schools under the Educational Area Office One of Nonthaburi province, Thailand. In academic year 2009, this educational area is composed of 94 schools for both private and public schools; 67 elementary schools, 18 opportunity extension schools, and 9 secondary schools. The organizational education of the schools normally has set as two-semester system per year. The first semester has started from May to September, and the second semester has started from November to March. Normally, there are two times of school breaks in each academic year; the first school break takes place in October, and the second one takes place from lastly week of March to middle of June.

This study was to investigate purposively insight 2 out of 9 upper secondary schools; Namsai Wittaya School and Tonnam Suksa School (Pseudonyms). However, the study focused directly on chemistry teachers serving as the cases who had willingness to be research participants in the context of teaching for CT. Both of schools have enrolled students from 7th grade to 12th grade. However, the difference of these two schools is that Namsai Wittaya School has only served for female students while Tonnam Suksa School has taught both males and females as co-ed school. These two schools located close to each other, having similar environment and local context in Nonthaburi province. The schools are surrounded with local context including an elementary school, a big temple, middle family houses, apartments, and economic buildings. The following paragraphs describe context of each school.

Namsai Wittaya School

Namsai Wittaya School is a public school situated in urban area at Nonthaburi province. The school is composed of 8 study buildings, 3 multi-purpose buildings, a temporary building, 2 large auditoriums, a small auditorium, a big library, a food land, language laboratories, computer rooms, science laboratories, chemistry laboratories, physics laboratories, biology laboratories, a large sport field, and playground. The main goal of the school is to develop students as skillful and practiced citizen accordance with student quality standards; focusing on the Basic Education Core Curriculum 2008 which declared obviously enhancing student abilities in communication, higher-ordered thinking, solving problems, applying life skill, and technological application. Students are expected that they should possess abilities in new technology and second languages. Furthermore, the school also aims to enhance teacher profession continuously in teaching and learning based on student-centered approach and promoting students in higher-ordered thinking. The school enrolls only girl students and provides a variety of special learning programs serving properly individual differences in different subjects such as languages learning program, mathematics learning program, and science learning program. In academic year 2009, there were totally 2,971 students ranking from grade 7 to 12. Each grade level of grade 7 to 12 had 10 classes; each class enrolled about 48-50 students. While each grade 10 to grade 12 had 12 classes per grade level; each class contained 45-50 students. There were 356 in-service teachers and 22 government employees. The school supported the students proper and enough facilities in sport land and apparatus, school activities, school trip, instructional media including material and equipment for scientific experiments. In academic year 2007, the school participated in the project of special science classroom under the Office of Basic Education Commission (OBEC) and the Institute for the Promotion Teaching Science and Technology (IPST). This project aim to promote student reaching to their highest potential based on their interests as well as the project is to nurture student scientific attitude and characteristics of a researcher. The school provides one special science classroom for each student grade 10-12. These special science students study under specific science curriculum along with additional academic activities different from general student classrooms, including science camp, training work with educators in the university, and doing scientific project. Since, the special science students are expected to be knowledgeable and desirable citizens, the teachers who were responsible to teach these science classrooms are required as expertise teachers. These teachers have to enhance their capacities in teaching science subjects by participating usually in professional development activities.

Tonnam Suksa School

Tonnam Suksa School is a public school located next to Namsai Waittaya School in Nonthaburi Province. The school has 6 study buildings, language laboratory, computer room, ICT study room, science laboratory, chemistry laboratory, physics laboratory, biology laboratory, science library, mathematics library, school library, 2 gymnasiums, food land, auditorium, and sport field. The school has nurtured students from grade 7 to 12. The main goal of the school is to develop students to be discipline, responsible, diligent, honest persons. The promotion of student ability in technology becomes outstanding. At the same time, all teachers have been motivated to integrate technology in many ways into their teaching. For example, the teachers had to design and use technological instructional media. In doing so, the school administers always push forward the teachers attending workshops or seminar relating to the development of ICT into teaching. In academic year 2009, the school enrolled totally 3,215 students. There were 18 classes for each grade 7 to grade 9. The average number of students per classroom was 43-47 students. For each grade 10-12, students were divided into 9-10 classes of 34-37 students in average. The school employed 155 in-service teachers. This school aimed to promote student science and mathematics achievement by setting up science-mathematics classroom project in academic year 2006. The project offered to students from grade 7 to grade 12; 3 classrooms for each grade 7 to grade 10 and 2 classrooms for each grade 11 and grade 12. The students were served additional science and mathematics academic activities beyond regular classroom such as science camp, added teaching on Saturday, and doing science project. The teachers who are selected to teach these classrooms require more science teaching experience and attending frequently science teaching and learning professional development activities.

In regard to the importance of science in daily life, these two schools have paid large attention to teaching and learning science. Students in all grade levels are required to enroll in science subjects. According to Thai National Curriculum Standards B.E.2551, Chemistry content is taught based on the National Science Curriculum Standards; sub-strand 3 matter and properties of matter. The guidelines of teaching chemistry declares to promote student-centered teaching and learning approach in which attempts to enhance student abilities in chemistry knowledge, scientific inquiry, scientific attitude, nature of science, and higher-ordered skills through group learning and hands-on and minds-on activities. In doing so, chemistry teachers aim to enhance their teaching profession through engagement in several workshops, seminar, and teacher learning program in order to learn and practice corresponding to new teaching and learning approach.

Research Participants

As qualitative study, the generalization is not goal of investigation. The researcher would like to provide in-depth understandings about chemistry teachers' understanding and teaching practices for CT through thick description relying on the context of research participants and surroundings. Three cases of the volunteer participants were involved in the study. The research participants were invited to the study under the three criteria: 1) they addressed a desire to improve competencies in teaching for CT in Chemistry, 2) they graduated majoring in Chemistry; they were expected having no problems in content knowledge, 3) they taught Chemistry for different student grades, so they were dealing with different concepts to share, and 4) they, importantly, were able to spent their time to participate in activities with an academic year of the PD program. According to these criteria, it can be inferred that the participant teachers held intrinsic motivation to develop their own understanding and teaching practices for CT, and were motivated towards professional learning; hopefully they paid attention to the professional development activities. Three chemistry teachers in this study were hired in two different schools composing of Ms. Tawan and Mr. Artid from Namsai Wittaya School, and Ms. Ratree from Tonnam Suksa School. They were different in teaching experiences, student grade levels, and background of students such as science-oriented classroom, general classroom, girl classroom, and co-ed classroom. In brief, background of the participants is showed at Table 3.2 below:

Table 3.2 Background of the Participant Teachers

Data	Participant Teachers		
Name	Ms. Tawan	Mr. Artid	Ms. Ratree
Gender /Age	Female/50	Male/53	Female/30
Education	B. Ed. (Teaching Chemistry) M. Ed. (Teaching Science)	B. Ed. (Teaching Chemistry) M. Ed. (Audio Visual Education)	B. Ed. (Teaching Chemistry)
Schools	Namsai Wittaya (All-girl school)	Namsai Wittaya (All-girl school)	Tonnam Suksa (Co-ed school)
Observed classes/students' number	10^{th} grade of a special science/ 37 female students	11^{th} grade of an ordinary science/ 47 female students	12^{th} grade of an ordinary science/ 36 students (20 males, 16 females)
Teaching periods a week	14 academic, and 1 extra activities	14 academic, and 3 extra activities	12 academic, and 3 extra activities
Chemistry teaching (year)	29	5	3
Teaching experience (year)	29	20	3

The Designed Professional Development Program on Teaching for CT

Increasing teacher pedagogical knowledge of teaching for CT, this PD program was designed upon a combination of professional development strategies under specific context of the study (Watts *et al*., 1997; Zoller *et al*., 2000a; Zohar and Dori, 2003; Zohar and Schwartzer, 2005; Lang, 2006). A framework to organize this PD program was based on the developmental principles of professional learning throughout collaboratively reflections and discussions on one's classroom practices as well as their understandings of teaching for CT also were considered having interrelated to teachers' changes in teaching practices for CT (Zohar, 2004; Lang, 2006; Torff, 2006). The program attempted to enhance in-service chemistry teachers' understanding of and teaching practices for CT in their own classrooms. The program was designed based upon teachers' context including teachers' background and experiences in teaching, students, school contexts. The principle of the program was enriching teachers' teaching for CT through collaborative learning among the teachers and the researcher based on their teaching. The significant features of this PD program emphasized on:

a) Concerning with participant teachers' backgrounds and teaching contexts

b) Concerning with participant teachers' prior understanding of and teaching practices for CT

c) Supporting the participant teachers to collaborative learning via discussions and reflections on their actual teaching

d) Providing workshop on teaching for CT to support participant teachers in "learning how to" teaching for CT

e) Monitoring participant teachers' changes in understanding of and teaching practices for CT, and encouraging them to reflect on their teaching

f) Providing long-term engagement, one academic year to support and follow gradual changes of participant teachers' teaching for CT

The PD diagram of the designed professional development program was drawn as below at Figure 3.1:

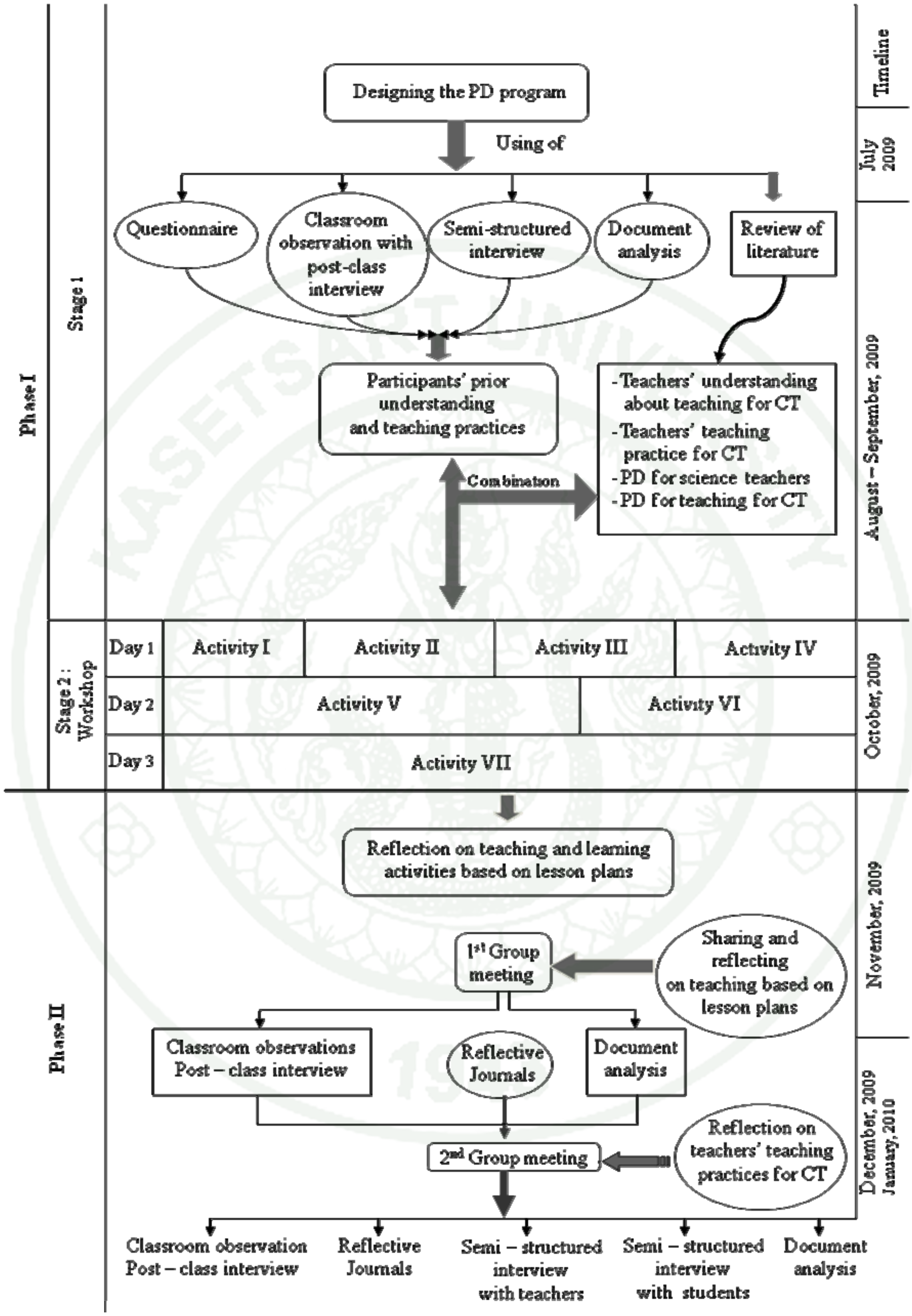

Figure 3.1 Diagram of the Designed Professional Development Program

The PD program involved two main phases consecutively: Phase I was the designing the PD program which was conducted in the first semester of academic year 2009. Phase II was the implementing and evaluating the PD program implemented in the second semester. Describing each phase, the following paragraphs are supported.

Phase I: Designing the Professional Development Program

Phase I aimed to design professional learning activities concerning to participant teachers' backgrounds and contexts of teaching. This phase was divided into two stages. Stage 1 was the examining participant teachers' prior understanding of and teaching practices for CT. The data from this stage was partially useful to design PD activities inside the workshop on teaching for CT as next stage. Stage 2 was the implementing the workshop on teaching for CT and planning about ways of follow-up the teachers' changes in understanding of and teaching practices for CT as the results of participating in the PD program. These two stages were presented as following.

Stage 1: Examining Participant Teachers' Prior Understanding of and Teaching Practices for CT

Stage 1 of Phase I was conducted to acquire participant teachers' prior understanding of and teaching practices for CT. To gather useful data, multiple methods of collecting data were employed including; classroom observations with post-class interviews, semi-structured interviews, a questionnaire, and document analysis. The researcher read and jotted down important information in the context of teaching for CT. The researcher then coded and categorized the information into themes leading to participant teachers' prior understanding of and teaching practices for CT eventually. Procedure of Stage 1 of Phase I was provided as the followings.

Data Collection before the PD Activities

Classroom Observations

Classroom Observations of three participant teachers took place during the first semester of 2009 academic year; 4 time observations for each teacher with different learning units. The researcher played role as a non-participant observer who just sat at the back of the room and took video-recorded. The classroom activities and teachers' teaching practices were jotted down as field notes. The classroom movement also was video-taped in order to prevent passing some significant events in the classes by the researcher. Each observation took about 50 minutes for one period or 100 minutes for two consecutive periods. The classroom observations focused on the ways that the participant teachers employed to conduct their classroom activities such as presenting new topics, using words about thinking and questions promoting students to think, treating students' wrong answers, engaging students in cognitive tasks, and assessment practices. In addition, frequencies of each happening in the classrooms were considered. After observe participant teachers' classroom practices, the teachers was interviewed by the researcher directly based on the observations. This post-class interview was to examine teachers' perceptions and thought about their lessons. The post-class interview was taken about 15-20 minutes for each interview. The questions concerned with how the teachers prepared the classroom activities, what the learning objectives were, and the successes or failures of the lessons. In addition, the participant teachers were asked to reflect on their own teaching relevant to promoting CT. For example: Are you concerned purposely with promoting students' CT in teaching? Which parts of the lesson promote students' CT? What makes it difficult for students to learn? How can student learning be improved? How can CT be enhanced? And what are some good ways to assess students' CT in chemistry? In addition, video-recorded of classroom activities were selected to be examples of classroom activities which were utilized in the workshop in Stage 2. Usefully, the data from all four data collecting methods detailed above enabled the researcher to gain a deeper understanding about teachers' understanding of and teaching practices for CT in chemistry.

Semi-Structured Interviews with Teachers (Initial Interview)

Semi-structured interviews were concerning to participating teachers' understanding of teaching for CT and their classroom practices: planning lesson, goals of teaching chemistry, teaching practices, assessment and evaluation practices, factors influencing teachers using learning activities and tasks, and capacities that the teachers wanted to increase themselves related to teaching for CT. The interviews also were flexible in some questions to inquire as much as information the teachers' understanding of teaching for CT and classroom practices. The questions, for example, were such like; 1) What are your goals of development students in learning Chemistry? 2) How CT benefits students? Do you consider teaching chemistry for CT? Why? How? 3) Is it possible to integrate teaching for CT in Chemistry? How? (Give me an example) 4) did you concern about classroom activities and tasks promoting students' CT? How did you do about such concerns? The interviews were conducted directly by the researcher. Each interview was recorded and taking about 20-30 minutes.

Open-Ended Questionnaire

The questionnaire consisted of open-ended questions and multiple choice items. There were three sections of the questionnaire. Section I concerned teachers' background information and teachers' needs to improve in teaching chemistry. Section II examined participant teachers' understanding about teaching chemistry in the context of teaching for CT including teachers' understanding of and teaching practices for CT, awareness of teaching and learning activities, characteristics of teaching for CT in chemistry, instructional media and assessment related to teaching for CT, factors influencing teachers' teaching for CT, and teachers' needs to increase in teaching for CT. The last section provided five rating scales of 12 items of teaching chemistry requiring the teachers to rate their opinions under the context of teaching for CT, and to rate their actual teaching practices also.

Document Analysis Related to Teaching

To support information from classroom observations and interview, the participant teachers were reviewed their documents related to teaching lessons such as lesson plans, worksheets, knowledge sheets, tests, students' laboratory notebooks, and instructional media. These documents supported the researcher to assess level of cognitive tasks that the teachers provided for their students as well.

Data Analysis before the PD Activities

The participant teachers' prior understanding of and teaching practices for critical thinking were analyzed by means of principles of content analysis. The researcher coded and generated important elements to categorize participant teachers' understanding of and teaching practices for CT emerging from the open-ended questionnaire response, transcribed classroom observations, post-class interviews, semi-structured interview, and analysis of document related teaching. In addition, the researcher took advantage of literature review of teachers' understanding of and teaching practices for CT combining with findings from Stage 1 to design professional learning activities inside the workshop. Individual participant teacher's teaching was analyzed by each case in the context of teaching for CT. Then, the researcher analyzed participant teachers' prior teaching by cross-cases.

Stage 2: The Workshop on Teaching for CT in Chemistry

The professional development program included three days of the intensive workshop on teaching for CT in Chemistry. This workshop was set up with principles of supporting the participating teachers in learning to know collaboratively how to teach for CT based upon their contexts and teaching experiences. The professional learning activities provided in the workshop were composed of lectures, demonstration of learning activities, doing inquiry-based chemistry learning, designing learning activities, presentation, writing and reflecting on lesson plans, discussions and reflections on teaching based on their actual classroom practices. The participants who attended the workshop comprised three participant teachers, two research advisors, one research assistant, and the researcher. The workshop took place during the first school break dividing into 2 consecutive days, and then one day after two weeks later. The activities within the workshop were almost video-taped by the research assistant. The workshop was composed of 7 activities including building rapport, think aloud how do students learn chemistry, what's CT, how to teach for CT, watching and reflecting on the actual teacher teaching practices, designing lesson plan related to teaching for CT, and analyzing and improving teacher lesson plan. The following is to describe briefly each activity.

Activity I: Building Rapport and Sharing Teaching Experiences

This activity was suitable to put as the first session, and took about an hour. Building rapport among the teachers and the researcher allowed significantly the participants relax and open mind to share and learn collaboratively with each other. In doing so, each participant presenting themselves what they were focusing on experiences in teaching chemistry and teaching for CT. This produced good relationship to do next activities together. The participants shared their ideas about roles of CT in competitive society nowadays; they were convinced to be more aware of the importance of teaching for CT in learning and real world. This activity also informed the participants an overview of the activities inside the whole workshop and what the teachers required to do. At the beginning, the researcher introduced backgrounds of each participant followed by goals of the workshop, and overview of activities within the workshop. The participants then presented themselves about experiences in teaching, the goals of teaching chemistry, opinions about teaching chemistry in the context of teaching for CT, characteristics of a desired student to learn chemistry, characteristics of an effective chemistry teacher, factors influencing on teaching for CT in chemistry, what they expected to gain from participation in the PD program, and how they planned to apply knowledge from the workshop into their actual classroom practices.

Activity II: Think Aloud: How Do Students Learn Chemistry

This activity took about 90 minutes. The main purposes of the activity were to share collaboratively and reflectively teacher opinions about how student learn, the terms of scientific knowledge, and important characteristics of scientists. The participants had an opportunity to do three sub-activities including; 1) learning via history of science or HOS activity, 2) what I *Know*/ what I *Want* to know/ what I *Learned* or KWL activity, and 3) ways of students knowing and learning. The participants discussed about exemplary scientific knowledge on atomic model and periodic table concerning to why did we have changes in knowledge about atomic model and periodic table, how did scientists gain knowledge about atomic model and periodic table, what important characteristics of such scientists were, and what students should possess to be an active learner in chemistry. Then, the participants discussed and reflected their understandings about scientific knowledge; fact, concept, theory, principle, law, and hypothesis. The participants also engaged in a learning activity named KWL; they had to make a decision based on daily life situation provided concerning scientific issues such as using NGV or LPG. They presented about what they had known, what they wanted to know, and what they had to do then related to the situation provided. The participants consequently discussed on their selected solutions with supporting reasons. For the last sub-activity, the participants listed basic apparatus using in chemistry laboratory. Then, they described how to use such apparatus accurately using chart of provided laboratory techniques. The participants also demonstrated using those apparatus. Finally, they all reflected what ways were suitable and practicable for promoting student learning chemistry. They also reflected on difficulties and availabilities that students might face during lessons.

Activity III: Tell Me! What Do You Mean by "Critical Thinking" and "Teaching for Critical Thinking?"

This activity aimed to assess teachers' prior understanding of and teaching practices for CT in chemistry as well as the activity was designed in order to motivate the participants for constructing collaboratively scope of teaching for CT in chemistry.

First of all, the participants planned and demonstrated how to solve two scientific problems: calculating volume of liquid, and testing for classifying plastic raw material. These two activities allowed the participants engaging in solving problem via hands-on and mind on activities as if they were students. Then, they raised a variety of questions based upon cognitive levels of Bloom's Taxonomy; knowledge, comprehension, application, analysis, synthesis, and evaluation. They also had an opportunity to analyze cognitive levels of learning objectives within chemistry textbook. The participants shared the meaning of CT and teaching for CT based on their understanding and provided document related to teaching for CT.

Activity IV: How to Teach for CT in Chemistry

This activity allowed the participants to learn teaching techniques related to the promotion of students' CT. The participants embed themselves in doing science through *P*rediction – *O*bservation – *E*xplanation or POE activity, and doing titration which was representative for significant hands-on and minds-on activities in Chemistry. To do titration, many scientific skills and chemistry concepts were required. These two activities supported mostly the participants to assess themselves knowledge in scientific experiment, techniques of using scientific apparatus. As well, the participants engaged in such tasks as if they were students which helped them to understand student difficulties with engaging in learning activities. Next, the participants designed collaboratively chemistry learning activities related to teaching for CT. Then, they discussed and presented the learning activity on topics learning objectives of content, difficulties of concepts to teach, designed learning activity to promote students to think critically, and assessment practices.

Activity V: Watching and Reflecting on the Actual Teacher Teaching Practices

With the main goal of enhancement of professional learning, analysis and reflection on actual classroom teaching was usefully required. Each participant was asked for permission to present a video-taped of actual classroom practices from Stage 1 of Phase I to be an example of lesson to all. The video-taped was selected appropriately by the owner and the researcher, and each classroom video took for 2 periods or 100 minutes. Watching each classroom was displayed by the researcher controlling forward and backward for discussing and reflecting on how to teach for CT based on the observations. The participants also analyzed teachers' teaching and learning activities pertaining to teaching for CT. They discussed and reflected how to improve such classrooms to encourage student learning and thinking as well as how to practice for assessing student learning and thinking.

Activity VI: Designing Lesson Plan Related to Teaching for CT

Lesson plan is a virtue instrument for teachers in teaching. It guides ways to teach for leading student to learning objectives. In order to support the participant teachers to design their lesson plans in the context of teaching for CT, they engaged in analysis of the example lesson plan provided by the researcher following by their own lesson plans. To analyze the lesson plans, the participant teachers utilized a protocol of analyzing and assessing form based upon teaching for CT. After analysis of lesson plans of each participant, they had an opportunity to collaboratively design learning activity and lesson plan together under a concept of chemistry; this lesson plan was directed to how to promote students' CT. They then reflected on weakness and strength of that lesson plan based on criteria of teaching and learning for CT. Each participant planned briefly their own one particular unit lesson; this plan was used to write full pattern of lesson plan two weeks before reflecting and improving for the whole lesson plans in the last day of the workshop. The participants were required to plan lessons based upon knowledge acquired from the professional development program. These lesson plans were used in their actual classrooms for the second semester of academic year 2009.

Activity VII: Analyzing and Improving Teacher's Lesson Plans

This last activity of the workshop aimed mostly to reflect and improve each lesson plans of the participants before they employed in the second semester. The focus of analyzing paid large attention on learning activities. However, lesson plan components based on the criteria of teaching and learning for CT were considered as well. With the limitation of time, each participant was analyzing deeply one lesson plan while others were asked for improvement by the participants based on knowledge gaining from the professional development program. Each participant and the researcher worked collaboratively to revise the lesson plans. These lesson plans would be used in teaching in the second semester, therefore the lesson plans might be changed to be suitable for teaching context.

Last activity in Phase I of the study, the participant teachers and the researcher made a schedule of professional learning activities to investigate in the second semester of academic year 2009. The schedule contained time table of classroom observations, chemistry concepts for observations, group meetings, semi-structured interview, and reflective journals.

Phase II: Implementing and Evaluating the Professional Development Program

With the expectation to enhance teachers' understanding of and teaching practices for CT, the professional learning activities were implemented and evaluated. After the participant teachers attended the workshop, and collaborative learning together, it was necessary to monitor how the participant teachers changed or developed their teaching chemistry in the context of teaching for CT. Therefore, this phase attempted to answer the main research argument whether the PD program impact on teachers' teaching for CT. The researcher then tried to describe through three sub research questions; 1) how do teachers' teaching practices change as a result from the professional development program? 2) What factors constrain or facilitate teachers' teaching for CT? And 3) what are significant features of the professional development program enabling teachers' teaching for CT?

Data Collection after the PD Activities

In order to collect data about effects of the PD program on teachers' changes in understanding of and teaching practices for CT, multiple research methods were employed. A variety of research methods supported research reliability as a triangulation strategy; data sources included classroom observation notes and video-recorder, post-class interviews, group meetings, semi-structured interviews with the teachers, semi-structured interviews with the students, reflective journals, and document analysis. Following described each data source.

Classroom Observations

In order to follow up on teacher learning, classroom observations took place after the participant teachers attended the workshop. The participant teachers were observed 5-6 classroom practices depending on a particular learning topic each teacher preferred to be observed while the researcher played the role as a non-participant observer. This happened about twice a week, and took around one to two months for each teacher. Each observation was video-taped and jotted down some significant classroom events on paper. Classroom observations focused on the way teachers organized classroom activities and interacted in their classrooms. The focus of classroom observations was the same focus as in Phase I of the study: classroom activities, engaging students in learning activities, using questions and words promoting students' thinking, treatment of students' mistakes or wrong answers, cognitive levels of tasks given to students, and earning assessment. After classroom observations, post-class interviews with teachers based on the observations were utilized. In the interview, the teachers were asked about what their learning objectives were, what promoted students' CT, and what obstructed students' learning or what were the limitations of their classrooms. Each interviewee was asked permission to be audio recorded and the entire interview took between 15-20 minutes.

Group Meetings

There were two times of group meetings among the participant teachers and the researcher within the second semester of academic year 2009. Each meeting took about 50 minutes. The main goal of the group meetings was to discuss about teachers' lesson plans based on classroom activities that they will conduct in their actual teaching. The group meetings involved collaborative discussions and reflections on teacher teaching experiences related to teaching for CT based on knowledge gained from the PD program as well. The group meetings were for teachers to reflect on their weakness and as a result, strengthened to the researcher's capacity to investigate teacher progression in knowledge on and teaching practices for CT. The participating teachers also indicated what factors facilitated and constrained their real teaching relying upon principles of the PD program.

Semi-Structured Interviews with Teachers (Final interview)

The semi-structured interviews took place nearly the final of each participant teachers' classroom observations. This interview aimed to determine what the participant teachers had learned and what their opinions about their development in the context of teaching for CT as the outcomes of their participating in the PD program. The teachers were asked about their understanding of teaching for CT in Chemistry, what the participant teachers practiced in their teaching to promote students' CT, what obstructed students' learning or what were the limitations of their classrooms, and how they assessed student learning in the context of teaching for CT. Each interviewee was asked permission to be audio recorded. Each interview took between 15-20 minutes during school time.

Semi-Structured Interviews with the Students

The researcher also interviewed each four students for each the participant teacher, in total 16 students for this interview. Some students were willing to be interviewed and some of them were indicated by their own the teachers. Conditionally, each student of each teacher was drawn from a group of students who got four different grades of chemistry excellent, good, fair, and poor. The students will be interviewed on nearly the last classroom observation of the second semester of academic year 2009. The interviews with students concerned with student attitude to chemistry subject, advantages and disadvantages of teacher teaching, characteristics of chemistry teaching preferred, and teacher teaching practices promoting student thinking. The questions, for example, were “what are your expectations in learning chemistry? Do you love to study chemistry, and why? Which activities should be employed in chemistry classroom and promote you great learning and thinking? How does gained knowledge from studying chemistry benefit you? Are there any changes of your chemistry teacher teaching throughout this academic year? And what should be changed or remained in your chemistry teacher teaching? In order to provide greater understanding about students’ answers, the interviews also added more questions related to students’ responses.

Reflective Journals

The participant teachers reflected on what they learned through their own teaching based on knowledge gained from the PD program such detail about what leaded students to goals of teaching, what obstructed student learning, what promoted student CT, teachers’ satisfaction on their classroom activities, and what should be kept or improved in the future teaching. The teachers wrote two times of teaching journal to investigate the change of teacher teaching based on classroom observations after the workshop. They also wrote one reflective journal on what they gained experiences in the context of teaching for CT from the PD program.

Document Analysis Related to Teaching

In order to support and cover information from classroom observations and interviews, a review of the documents that teachers constructed and utilized in their teaching was employed as well as students’ assignments and products of study were analyzed. These documents composed of lesson plans, the teachers’ teaching journals, tests, tasks, learning activity sheets, knowledge sheets, and students’ laboratory notebooks. The researcher read and looked for significant evidences related to focus of the study within the documents that promoted or obstructed student learning or thinking. The document review allowed the researcher to add evidence about how teachers change knowledge and teaching practices for CT.

Data Analysis after the PD Activities

Content analysis were used for analyzing gathered data and pointing out what changes occurred in the teachers' understanding of and teaching practices for CT as the results of the PD program. Data from the group meetings were transcribed to investigate teachers' comments during the meetings where they discussed and reflected on classroom activities. Data from the observations were coded into a categorization of teaching practices based on teaching for CT.

In order to compare and see how much teachers changed or improved themselves in their teaching, semi-structured interview data were coded to outline how teachers' changed their own understanding of teaching for CT and how they coped with a variety of classrooms and lessons pertaining to teaching for CT. Documents of tasks that participant teachers produced during engaging in the PD program were also reviewed. All of findings were used to represent how teachers changed as an outcome of their attendance in the PD program.

Essential Pedagogical Development of Teaching for Critical Thinking

In analyzing of teachers' understanding of and teaching practices for CT, the researcher summarized the guided features of essential pedagogical development of teaching for CT drawn upon a review of literature in this research area. The features of essential pedagogical development would be helpful in a within-case analysis in Chapter IV and a cross-case analysis in Chapter V in order to examine teachers' prior teaching for CT and determine their changes in teaching for CT as an evaluation of effectiveness of the PD program. The features of essential pedagogical development adopted mainly from frameworks of Zohar (2004), Torff and Warburton (2005), Zohar and Schwartzer (2005), and Lang (2006) as in Table 3.3.

Table 3.3 Essential Pedagogical Development of Teaching for CT in Chemistry

	Components	Essential pedagogical development features
Understanding	Meaning of CT	Ability to reflective, reasoning, inquired, and logical thought using evidences and information in order to solve a problem, make a decision, and draw a conclusion
	Awareness of teaching for CT	Recognizing importance of CT in studying and living in this fast-paced and competitive world, teachers' role to teach for CT, CT and content knowledge enhancing each other, all students able to develop CT, CT can be integrated in standard school subjects.
	Identifying teaching for CT	Engaging students in participation in hands-on and minds-on activities: i.e. group works and discussions, solving problems, asking cognitive questions, inquired-based experiments, organizing data for presentation, and applying content knowledge to daily life
Teaching Practice	Goals of teaching	Nurturing students to be critical thinkers who reflect on reasons and evidences relevant to a decision or solve a problem as well as open-mindedness and active persons
	Teaching preparation	Planning learning activities for supporting individual different learning and CT and designing ways to diagnosis of students' difficulty in learning and ways to help them
	Classroom activities	Conducting various classroom activities emphasizing students' participation i.e. cooperative learning, inquiry-based laboratory, dealing in class with real-world, and presentation
	Strategies to engage students in learning activities	Using appropriate and various techniques as internal motivation to encourage students' attention on lessons i.e. using real and current situations, discussing based upon experiments, solving problems requiring reasons and evidences with enough time

Table 3.3 (Continued)

	Components	Essential pedagogical development features
Teaching Practice	Questioning techniques and treatments of students' responses	Using open-ended questions like "Why" and "How" requiring students' reflective and reasoning thinking and words for thinking i.e. observing, comparing, contrasting, classifying, inferring causes-effects, and predicting, and using students' wrong answers to drive discussion in classroom
	Cognitive levels of tasks given to students	Providing a variety of high cognitive tasks and learning activities which emphasize students' completing tasks by individuals or groups
	Learning Assessment	Assessing both processes and products of students' learning via a variety of assessment methods to seek students' learning outcome, and then help them to improve i.e. a paper-and-pencil test generating open-ended questions requiring students' reasoning abilities, and assessing students' doing experiment involving designing an experiment, discussions and conclusions based on evidences and data of experiments.

Limitation of the Study

This interpretive case study investigates with three Chemistry teachers; this is a few numbers of participating teachers. Therefore, the results of this study shall not be generalized to other Chemistry teachers or other science teachers rather the results aim to provide essential implications for in-service Chemistry education researchers and professional development leaders in order to enhance teachers' competencies in the context of teaching for CT. The focus of the study is paid to enhancement of participating teachers' understanding of and teaching practices for CT in Chemistry; the researcher therefore respects to teachers' content subject matter. The study has no assessing participating teachers' content knowledge prior to participate in the PD program; this might affect how they incorporate knowledge of pedagogies and knowledge of content together if they are difficult in some teaching concepts. Furthermore, the study has a few classroom observations (4 times before the workshop and 6 times after the workshop); this possibly skewed findings. It is difficult to conduct a number of classroom observations under conditions of the study: conducting different schools and gathering data at the same period of time. These two factors limit time table of classroom observations for each teacher.

Trustworthiness of the Study

The construction of trustworthiness of the research study was supported through three important criteria including credibility, transferability, and dependability. Credibility or internal validity represents the extent to which the research findings can be interpreted in accurate means (Wiersma, 1991) or how to establish the confidence in the truth of the finding in a particular study (Guba and Lincoln, 1981). The process of analysis in qualitative study which produces thick and deep description has to establish interpretive consensus (Andrade, 2009). Transferability or external validity refers to how much the research findings can be extended for larger populations and conditions or to other contexts (Guba and Lincoln, 1981; Wiersma, 1991). Correspondingly, if the research lacks of credibility, the research does not have transferability**.** Dependability or reliability is concerned with the consistency and reliability of findings of studies when the research studies are repeated in methods, situations and context (Guba and Lincoln, 1981; Wiersma, 1991). In order to ensure the quality of qualitative research, it is appropriate to consider dependability along with credibility and transferability.

The trustworthiness of data collection and analysis is a very important challenge for the qualitative inquiry to make believable research findings through providing how data is collected and analyzed as a way to represent the quality of the study. Qualitative researchers have to build systematic coding in research studies. In order to create believably trustworthiness of the data collection and data analysis, triangulation by means of multiple data sources including group meetings, classroom observations, semi-structured interviews, and document review related teaching were employed. Each transcript of the teachers' activities were read and re-read to categorize and code in order to check the teachers' understanding of and teaching practices for CT which supported accuracy and consistency of categorization and code. Considerably, three criteria should be considered, including: credibility or internal validity, transferability or external validity, and dependability or reliability referring ways to create trustworthiness of the study (Guba and Lincoln, 1981; Wiersma, 1991).

Summary

The study aimed to examine the effects of the PD program on teaching for CT on three in-service chemistry teachers in Thailand. Interpretive research is the paradigm followed in this research. A case study was used as the design of research, and content analysis and within-case and cross-cases analysis were the main method of data analysis in order to construct meaning from the research findings.

There were two main phases of the PD program of teaching for CT. Phase I aimed to design the PD activities based on participant teachers' contexts and their prior understanding of and teaching practices for CT. Data was collected by use of classroom observations, semi-structured interviews, open-ended questionnaire, and document analysis. The data was analyzed by coding and categorizing of participant teachers' understanding of and teaching practices for CT. Before starting Phase II, the participant teachers had an opportunity to attend 3 days of professional development workshop on teaching for CT in chemistry. This workshop aimed to enhance participant teachers' understanding of teaching for CT through collaborative learning among the teachers. The workshop also provided the guidelines for teaching and learning activities and encouraged the teachers to apply these to their classroom practices. Next, Phase II was to implemented and evaluated professional learning activities in participant teachers' changes as results of participation in the PD program. The data in this phase was gathered through group meetings, classroom observation, semi-structured interviews, and document analysis. The changes of teachers' understanding of and teaching practices for CT were assessed by comparing with the findings before the workshop.

CHAPTER IV

FINDINGS OF THE THREE CASES

Introduction

This chapter reveals findings about understanding and teaching practice for critical thinking (CT) from an analysis of three individual chemistry teachers: Ms. Tawan, Mr. Artid, and Ms. Ratree. The findings emerge from multiple data resources gathering for the same data. The data is analyzed interpretively responding to the research inquiry how a professional development program (PD) changes participant chemistry teachers' understanding of and teaching practices for CT. The presentation of each case is then organized for conceptualizing the effects of the professional development program on the participant teachers. In description of each case involves participant backgrounds, student backgrounds, and classroom setting. The findings also are discussed both before and after the PD activities for these areas: teachers' understanding of teaching for CT and teachers' teaching practices related to teaching for CT. Factors influencing on teachers' teaching for CT are revealed.

Case I: Ms. Tawan
An Experienced Chemistry Teacher

Participant Background

This information of Ms. Tawan's background was drawn from a questionnaire and interviews with the teacher. Ms. Tawan, an experienced Chemistry teacher, is a female in-service chemistry teacher who is 50 years old. She has 29 years experience in teaching science and chemistry. Ms. Tawan has worked in the Namsai Wittaya School at Nonthaburi Province for 10 years, teaching science subjects and chemistry. Ms. Tawan graduated with a Bachelor's Degree in Teaching Chemistry. She further developed her teaching ability and profession by completing a Master's Degree in Teaching Science. She likes to attend workshops or seminars about teaching and learning science. In doing so, she is admired and respected for her teaching effectiveness by her colleagues. Evidently, she has been selected to teach in the "special science classroom" which is composed of the students who have set their minds on a future in Chemistry, Physics and Biology. The special science classroom requires science teachers who are able to teach effectively in the areas of scientific process, scientific skills, and scientific knowledge, applying science into real life. With these commitments, Ms. Tawan has worked with the special science classroom in the tenth grade for three academic years consecutively; from the beginning of the special science classroom project in academic year 2007 up to the present. Regarding to above information such as many years in Chemistry teaching experience, working with groups of science-oriented students, and occasional attending professional learning activities, The researcher named her as an experienced Chemistry teacher.

In the first semester of the academic year 2009, Tawan taught students in grade 9, grade 10, and grade 11. She taught a scientific project subject for two classes of ninth grade students. There were 43 students in one classroom and 45 students in another. She also took responsibility for teaching Chemistry for two courses for a special science classroom of 37 tenth grade students. She was also involved in teaching Chemistry for 3 periods a week for an ordinary science class of 45 grade 11^{th} students. In the second semester, Tawan taught the same subjects for grade 9 and 11, but she taught chemistry for two classes of grade 10; one was the same special science class, another was 45 tenth grade students in an ordinary science classroom. Tawan also had taken further responsibility in finance and accounting affairs of the school. In her point of view, this duty became an important factor that affected her time management for preparation and concentration on academic teaching.

Two previous years before this study, Tawan had attended workshops related to teaching and learning science as a requirement of teachers who teach the special science classes. She involved in PD activities about designing teaching and learning activities based on Active Teaching and Learning Approaches in Science [ATLAS], and one day of learning science to promote students' higher-ordered thinking (HOT). Ms. Tawan said that she wanted to promote students' thinking, but only one day of listening to an introduction to HOT was not enough for enabling her to link theory to practices.

While the researcher introduced the PD program to Ms. Tawan, she immediately decided to collaborate in the research study. She said in an early informal conversation with the researcher that it was the responsibility of teachers to increase and adapt their knowledge and teaching practices related to teaching subjects. She stated that CT ability is essential for all people in the real world also. According to the initial interview, she would like to attend this professional learning activity in order to support her knowledge and learn how to conduct classrooms to promote students' CT. She appeared to become involved in the research study with her inner motivation.

The researcher observed the classroom practices of Ms. Tawan 10 times throughout two semesters of the academic year 2009. The observations were divided into two sessions: 1) before the PD activities, Ms. Tawan's teaching was observed 4 times: two experiments (titration and nutrition testing) and two lectures (titration techniques and titration calculation), and 2) after the PD activities, Ms. Tawan's teaching was observed 6 times including: ionic bonding, ionic structure and name, covalent bonding, molecular shape of covalent, polar and non-polar molecules, and students' presentation of petroleum concepts.

Student Background

The researcher observed Ms. Tawan's classroom practices in the special science classroom of 37 tenth grade students. All of the students are girls who came from middle-class socioeconomic families. There were high expectations for most of the students, not only by the school, but their parents also. They were expected to pass important tests and academic competitions such as Ordinary National Education Test (ONET), Academic Olympic Competition, and entrance examination to famous faculties and university which may lead them to a good career in the future. In the first semester the students took two interrelated courses with Ms. Tawan; studying chemistry in the lecture room and practicing techniques in the chemistry laboratory. They took 3 periods of 50 minutes a week for each course. In the second semester, the students took only a chemistry course with Tawan, 3 periods a week. Throughout the academic year 2009, the students did tasks in the same groups of three students.

Classroom Setting

In the classroom setting, the student's seats were set into four rows with three rows divided into two sub-rows, another divided into three sub-rows. They served a pair of students, and three of the students sitting together. In the special science classroom, air conditioning and computer sets were prepared in the classroom unlike the ordinary science classrooms. There were 6 computer sets connected to the Internet, and served the students for researching academic or school activities. There was a small bookcase containing journals and science textbooks in back of the room. The wall was decorated with things that related to scientific issues and school activities i.e. illustrations, maps, and diagrams. The teacher's table was located in front of the room at the left corner. The teacher also had a LCD projector set to support the presentation in teaching; the whiteboard was located in front of the room.

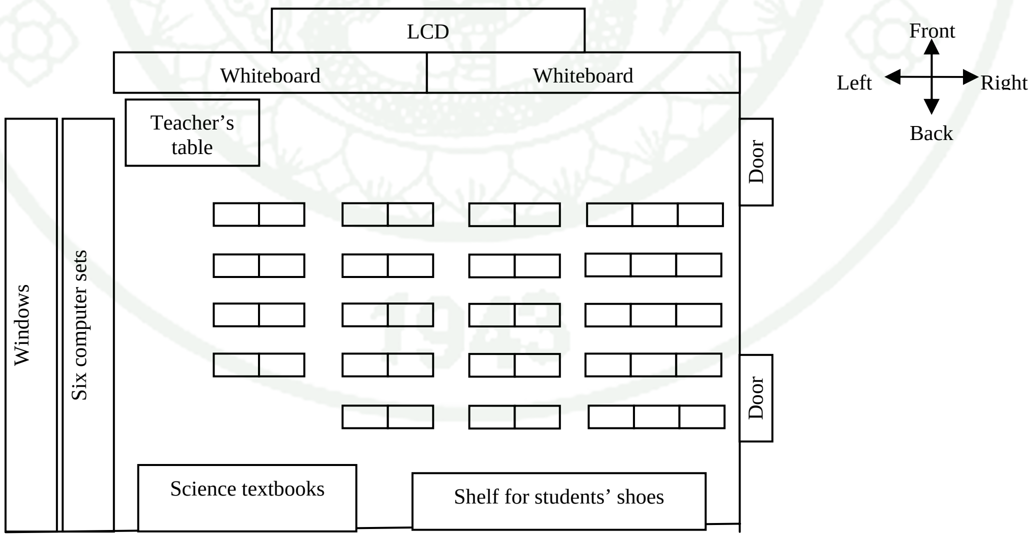

Figure 4.1 Layout of Special Science Classroom of Grade 10

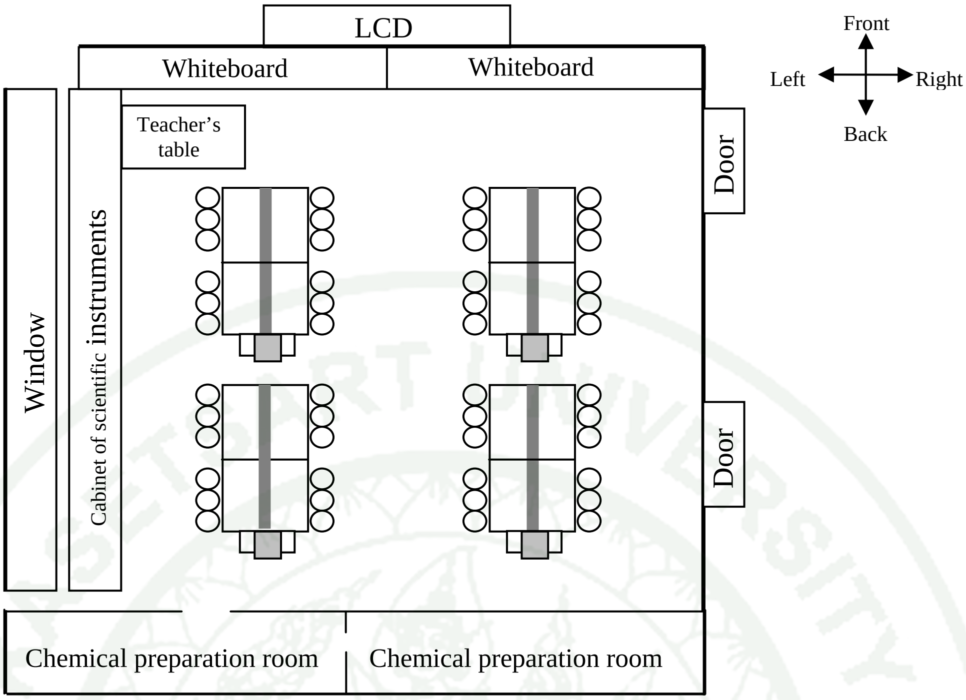

Figure 4.2 Layout of the Grade 10 Special Science Laboratory

Another classroom is the chemistry laboratory as Figure 4.2 used only by the students of the special science class. It is designed with the purpose of convenience in performing experiments. It is composed of 4 counter sets separated into two sides for each; the counters are set in the middle of the laboratory. There are two groups of three students each side of counters performing an experiment on the same counter. Each counter has a washing sink. There is a whiteboard and LCD projector in front of the laboratory for presenting or displaying experiments. There are two separate rooms inside the laboratory where basic laboratory materials, equipments, chemicals are kept, as well as a small room used for chemical preparation.

Findings about Ms. Tawan's Teaching for Critical Thinking

The following sections involve a discussion of research findings about Tawan's understanding of teaching for CT and teaching practices for CT. Regarding to the findings before the PD activities, the researcher did not manipulate the teacher teaching. These findings helped to answer the first research question: what is the chemistry teachers' prior understanding of and teaching practices for CT? Then the discussions pay attention to how the teacher changed her teaching as the results of participating in the PD activities. This part of discussion responds to the second research question: How does the PD program impact on teachers' teaching for CT?

The Findings before the PD Activities

Understanding of Teaching for Critical Thinking

In order to examine the teachers' understanding of teaching for CT, analysis of the teachers' responses to a pre-workshop questionnaire and interviews were considered. With regard to Tawan's prior understanding of CT, according to the questionnaire, she perceived CT as abilities to analytic and classifying thinking. During the initial interview, Ms. Tawan said that CT was essential for people to deal with various situations in the present and the future. It also represented higher-ordered skills used in making a decision. As Tawan stated in the interview;

> It is necessary to teach students to think. In real life, they have to seek knowledge from various resources; there is a huge amount of information provided. But, do they classify what is true or false? In the chemistry, there are quite accurate answers, what's *Right* or *Wrong*. Differently, in working place and the real world, they have to deal with a great deal of raw data. They need to know how to pick and choose the infallible data.
>
> (The initial interview: August 10, 2009)

Awareness of teaching for CT was expressed; teaching for CT was difficult and hard work for teachers, but teachers were required to do so. She said, "A teacher is a key factor for developing students' learning and thinking. The teacher has to organize the classroom and environment surrounding to motivate students' thinking" (The initial interview: August 10, 2009).

During the workshop, Tawan emphasized the importance of CT; she was not worried about her students' content knowledge rather their thinking and process skills. Ms. Tawan indicated that the teacher had to give an opportunity for students to ask questions because they naturally liked to express their ideas and thinking. According to Tawan, another way to teach for CT was discovery learning. Tawan stated after engaging in the workshop's activity II (Think aloud: How do students learn?):

> …I found, encouraging students in learning activities like the KWL activity promote their CT. Also, seeking information by themselves offered them the chance to develop their CT and learning. The students would plan about what and where they should gain data from using Internet browsing.
>
> (The first day of the workshop: October 27, 2010)

It appears that Tawan indicated teaching to promote students' CT during the workshop by asking student questions, and searching interested information from the Internet (Perkins and Murphy, 2006; Simpson and Courtney, 2008).

Teaching Practices for Critical Thinking

This section presents teacher's teaching practices categorized into 6 themes including: goals for teaching and teaching preparation, classroom activities, Strategies to engage students in learning activities, questioning techniques and treatments of students' responses, cognitive levels of tasks given to students, and learning assessment. The focus of the analysis considers how Tawan demonstrates such themes related to teaching for CT (Barak *et al.*, 2007; Malamitsa *et al.*, 2009).

Goals of Teaching and Teaching Preparation

Ms. Tawan, before the PD activities, expressed her goals of teaching chemistry focusing on nurturing the students in basic knowledge and skills based on school curriculum such as subject matter and scientific process and skills. As she stated in the initial interview, "I try to nurture the students in accordance with students' desirable characteristics based on the school requirement. The desired student is a person who is a skillful, active learner and effective thinker" (The initial interview: August 10, 2009). In post-class interview of a titration lesson, she noticed ways to process the lesson that, "It is the first time for these students in "titration". Thus, I have to tell them the meaning of titration. Then I will tell them about the benefits of titration. They also do not know about "mole" before; it is good to teach about mole briefly. Next, I will need to describe the process of titration" (Interview: August 10, 2009).

Enhancing student thinking ability was one of her stated goals in teaching, according to the questionnaire and her initial interview; especially the special science students themselves who wanted to succeed in their learning outcomes both in the school and in future study. This finding infers that Tawan recognized what the school expects her to develop students in knowledge and abilities. But, the focus of her goals seems to pay for chemistry concepts based on the curriculum.

To investigate how the teacher prepared before teaching, the data from her interviews before the PD activities showed that Ms. Tawan planned classroom activities relying on learning outcomes indicated in the curriculum of this special class which Ms. Tawan helped design. Planning lessons, she would outline the course syllabus for the whole semester. She spent the majority of her planning time for preparing learning activities, assignments, assessment, and reviewing the content knowledge. Tawan focused on promoting students' understanding about content knowledge, and scientific skills. As her statement based on interviews before the PD activities:

Researcher: How do you prepare your teaching?

Ms. Tawan: In practice, I focus on learning activities and preparing experiments.

Researcher: Learning activities and experiments, anything else?

Ms. Tawan: Um, I am one of the team that developed this special science curriculum. So, I know it very well. I will design classroom activities based on learning objectives in the curriculum.

Researcher: How about content knowledge, what do you do?

Ms. Tawan: Typically, I seldom prepare or spend time on content knowledge. With more than 20 years teaching experience in chemistry and working with science classrooms, I think I am good in content knowledge. So, I do not worry about it.

(Interview: August 31, 2009)

It is seen that, subject matter did not make serious for her. However, the analysis of interviews and lesson plans prior to the workshop, she did not concern herself about learning activities or assignments related to promoting students' CT.

Classroom Activities

According to classroom observations before the PD activities, Ms. Tawan generally implemented lessons with three main pedagogical steps: introduction to what the class was going to learn or talk to current school activities, instruction with focusing on content knowledge and principles to deal with teaching concepts and skills, and conclusion of what was learned from the classes. Ms. Tawan taught two experiments and two lecture-based lessons for the period of observation where the researcher was present. In the laboratory, Tawan began the lesson by giving the students about the procedure of the experiment step-by-step. At the same time, she drew the steps of the experiment on the whiteboard. Tawan also allowed the students to ask the questions related to the experiment before starting the experiment, but, based upon observations, the students did not ask questions at that time. They had questions relevant to the procedural during doing the experiment. Next, the students did the experiment with their groups. Some students prepared materials and chemicals, some tested nutrition, and some recorded findings. The researcher observed that students looked familiar in using experimental instruments, but they still made mistakes and were careless in some steps; they contaminated the experiment by using the same stirring rod with different testing materials without cleaning, they did not use safety tools such as marks or gloves dealing with strong and concentrated acid. While the students did the experiment, Tawan walked around and observed them. In the last step of this lesson, Tawan asked the students to complete the experiment and note the data based on testing. Then, all groups cleaned up the laboratory and wrote their experiment report to the teacher before the next period.

Following period to the experiment, Tawan and her students summarized their results and draw conclusions based on the experiment. However, Tawan appeared directed in conclusions. Therefore, the class presented little of students' discussion and expression of their thought. This was not seen to challenge students to think critically (Malamitsa *et al.*, 2009; Matchett, 2009). In Tawan's opinion about her teaching based on post-class interview, she said that she was satisfied with this group of students doing the experiment. She reported:

Researcher: What do you think about the students' doing experiment?

Ms. Tawan: This group of students is quite active learner. They always participate in learning activities.

Researcher: Do you think they did well in the experiment?

Ms. Tawan: I am satisfied with them. Most of them are new at using scientific instruments. They come from different schools, so some rarely used such instruments or did scientific experiment.

Researcher: What have students learned in this lesson?

Ms. Tawan: I think they learned about scientific process, doing scientific experiments, and group work.

Researcher: Do the lesson develop their CT?

Ms. Tawan: I think to some extent. This experiment is qualitative testing. We do not need to use exact amount of materials to do the testing. Thus, they just perform based on how to test and analyze. This also motivates their critical thinking critically.

(Interview: August 26, 2009)

Regarding to lecturing classroom, at the beginning of the lesson, she would encourage the students to pay attend to the teaching content by telling them the meaning and the usefulness of the topics. For instance, to study techniques of titration, she told the students that,

> Titration, what is it, what its benefits are, what its techniques are, and what its procedure is? That's all we will study about titration. We'll start with what is titration? Ok, it is a technique to examine the concentration of solution. But, because you don't know the meaning "concentration" already, we need to talk about this first" (Classroom observation: September 16, 2009).

Then, Tawan taught content knowledge based on learning objectives. For example, she explained the steps to calculate the concentration of an unknown solution. She raised questions in order to probe students' attention to her teaching, but the questions required short answers and the class presented mostly teachers' talk. For example, she used an exemplary calculating problem based upon data of titration between unknown A 25 cm^3 and 0.1 mol/dm^3 of standard solution B which was used 25 cm^3. For example, the following observed conversation was recorded as below:

Ms. Tawan: Okay, what you have to know or what important data to use in the calculation consists of 1) how much volume of unknown solution? So, what is the unknown solution?

Students: Solution A

Ms. Tawan: Solution A, another data is the standard solution is; that is solution B. So, it means that we knew already about B both what B is and the concentration of B. This situation used 0.1 mol/dm^3 of B. Here I provide you already balancing chemical equation. I set that $A + B \rightarrow C$, so, the ratio of chemicals is "1". This means that 1 mole of "A" reacts equally with 1 mole of "B". So, we now have completed data for calculating. We will calculate both formula and conversion factor. Which one first?

Students: Formula

Ms. Tawan: Ok, start with calculation based on formula first.

(Classroom observation: September 16, 2009)

In the last step of teaching, Tawan summarized classroom learning focusing on key concepts in the lesson. She closed lessons by briefly repeating key concepts or steps to solve problems in titration. The students rarely interacted; they naturally sat in their seats and appeared to be listening to the teacher.

The findings based upon observations and interviews before the PD activities appeared that Tawan conducted classroom activities concentrated on her talking about content knowledge. She provided experiments for the students, but the experiment lessons seemed not to encourage students to think critically. The students followed steps of the experiments with few expression their thought.

Strategies to Engage Students in Learning Activities

In the early classroom observations, Tawan encouraged her students to pay attention to learning activities by calling for volunteers to demonstrate the uses of particular instruments in titration. It seemed that most of the students paid great attention to such demonstration and seemed to be inquisitive learners. The teacher also mentioned, based upon interviews, that it was a good way to assess student skills using scientific instruments; she could know which skills needed to be focused to develop the students' ability to conduct doing scientific laboratory work. Tawan also engaged students in lessons by allowing them to do experiments as already mentioned in topic of classroom activities. Ms. Tawan engaged the students in lessons by reminding them the reasons why they needed to focus on learning. She was looking to further academic competition as a major goal of this group of students. For instance, she encouraged the students to be aware of doing titration such like: "Most of you plan to take the Olympic Competition, right? If you win the first section of the competition, you of course will have a chance to work with scientific experimentation. For chemistry, titration seemed to be typical testing for you" (Classroom observation: August 31, 2009).

It appeared that Tawan practiced in engagement of students in lesson in some extent. Almost all of the students appeared to participate in activities provided.

The students would develop their CT through engaging in tasks and scientific experiments (Bailin, 2002; Simpson and Courtney, 2008; Ketsing, 2010)

Questioning Techniques and Treatments of Students' Responses

Ms. Tawan stated in the initial interview that questioning was a good technique to encourage the students to think critically as well as using questions to encourage students' attention. Hence, she used and added more questions depending on students' responses. However, it seemed to be that most of the questions required short answers, and she answered the questions herself. A dialogue presents finding the concentration of HCl 15 cm^3 which reacted with 0.1 mol/dm^3 of NaOH 20 cm^3.

Ms. Tawan: First of all, you have to know, what does this problem provide? Take a look! It contains what? Concentration of what?

Students: Sodium hydroxide (NaOH)

Ms. Tawan: Um, we know the NaOH concentration, how much of it?

Students: 0.1

Ms. Tawan: Ok, NaOH is 0.1 mol/dm^3. Anything else we know?

Students: Volume.

Ms. Tawan: Um, volume of what? Volume of NaOH, How much?

Students: 20 cm^3

Ms. Tawan: Um, 20 cm^3 of NaOH, we also know volume of what?

Students: Volume of HCl.

Ms. Tawan: Yes, volume of HCl, how much?

Students: 15

Ms. Tawan: 15 cm^3, anything else within the problem, anything else?

Students: No, that's all.

Ms. Tawan: That's the problem offered; what does the problem asks for?

(Classroom observation: September 19, 2009)

Ms. Tawan argued that whenever she asked questions, it did not matter if the students presented some mistakes or wrong answers; rather she desired to motivate the students in responding to the questions and expressing their ideas as the main purposes. As Tawan stated in post-class interview of testing nutrition lesson;

> I typically observed whether they did something wrong during doing experiment or not. I might see they were using experimental materials in wrong ways; if it was not seriously dangerous, I let them go on, and then I advised in the whole class how to use it in the right way.
>
> (Interview: August 26, 2009)

Ms. Tawan responded to her students' responses in several ways such as; repeating the questions, rejecting immediately, ignoring and asking for additional the students to respond the questions. For example, as teaching titration techniques, she raised pipette up and asked the students to name it. As below:

Ms. Tawan:	Which type of instrument do we use for transferring Solution A to flask? We use this one, what is it?
Students:	Burette (wrong answer).
Ms. Tawan:	What? What is its' name? We just watched it on VDO?
Students:	Burette, (closed time some students answered) Pipette.
Ms.Tawan:	Burette or Pipette?
Students:	Burette, Pipette (there were two answers from the class)
Ms.Tawan:	Look at this (hold up a Burette); what has a volume scale?
Student:	Burette.
Tawan:	So that is a Burette, how about this one (pointing to a Pipette)
Student:	Pipette.

(Classroom observation: August 31, 2009)

Ms. Tawan said that she used questions to promote students' CT. Nonetheless, before the PD activities, Tawan's questions appeared to be yes-no and close-ended questions such like above examples which seemed not to require supporting reasons. She responded to students' responses in several ways, but she did not use such responses to challenge students' discussion and expression about their ideas. It was recognized that these types of questions and such Tawan's feedbacks to students' responses are not indicated to promote students' CT (Slack, 1997; Zohar and Schwartzer, 2005; Simpson and Courtney, 2008).

Cognitive Levels of the Tasks Given to Students

As Tawan's statement earlier that she aimed to promote students' CT particularly for the special science class. Therefore she provided complicated tasks for them such as doing experiments and demonstrating. Most of them, however, were not observed using such tools properly; especially when they were new at titration. To teach students how to calculate in titration, Tawan would present them step-by-step and remind them to memorize the step during their taking the Olympic Competition. Therefore the results in this section suggested that Tawan implemented such tasks relevant to teaching for CT in a small extent.

Learning Assessment

The findings of how Tawan assessed students' learning before attending the PD activities. Ms. Tawan assessed student learning by utilizing tests, tasks and doing scientific experiments and reports. Scoring from testing was weighted as a majority of students' academic achievement. Based upon the initial interview, she graded the students depending on 50% of total scores from mid-term and final tests. There were about 10 points rated from students' desirable characteristics set by the school with these 10 points, Tawan also considered the development of the students individually. She talked to the students about what they were doing wrong and waited to see any change and improvement in further classes; it included students' turning in all of the assigned tasks. Other scores came from doing tasks within the lesson, scientific skills, and experimental reports. These assessment methods were employed in order to examine students' development in learning and scientific abilities. Though she mentioned the importance of teaching for CT, she did not mention to assessing students' CT in her teaching chemistry. Therefore, the findings before the PD activities from this case analysis suggested that Tawan seemed not to concern how to assess or determine students' CT.

The Findings after the PD Activities

Understanding of Teaching for Critical Thinking

Ms. Tawan, after the PD activities, described meaning of CT related to her classroom teaching. Based on interviews, Ms. Tawan could articulate that "critical thinking referred to higher-ordered thinking related to complicated skills requiring reasonable, reflective, analytic, and decision making abilities" (The final interview: January 29, 2010). Tawan indicated in her reflective journal that teaching for CT involved students' actual participation in learning activities that enabled students to learn and think. She addressed some teaching for CT such designing scientific experiments, researching and presenting particular topics, group work, and lectures providing effective questions. She developed her understanding about CT activities through participation in the PD program as she reflected in the final interview:

Researcher: Was the workshop useful for you? If so, how?

Ms. Tawan: Yes, it benefited to me a lot to engage in the workshop; I can link knowledge with my classrooms. In the workshop, you used questions that motivate us to think about the activities.

Researcher: Can you give me an example?

Ms. Tawan: Likely questions during the POE activity and Blooms' Taxonomy. Therefore, I use questioning techniques to encourage students to think. In the classroom, I asked them more often, "Do you have any questions?" I also assigned them to provide 15 questions in order to assess their peers' understandings based on their research topics. They could learn by asking questions.

(The final interview: January 29, 2010)

Tawan seemed to increase her understanding of CT and teaching for CT after the PD activities; she addressed more critical thinking activities than before workshop where she focused on doing experiments and using questions.

Teaching Practices for Critical Thinking

Goals of Teaching and Teaching Preparation

After attending the PD activities, the data from interviews and reflective journal showed that beyond content knowledge Ms. Tawan aimed to develop the students' problem solving skills and CT abilities. She said in the final interview that, "The students should be able to discuss and report experimental results based on actual findings. They should not edit the finding following the theory, rather they needed to reflect Why or What might affect their experiment results" (The final interview: January 29, 2010). Tawan appeared to express goals of teaching relevant to thinking critically than content knowledge or academic examination. She also prepared about learning activities to promote student thinking whereas before the PD activities she focused on developing students in content knowledge. She had thinking about how to help her students learn about abstract content. As Tawan stated in her reflective journal based on classroom practices:

> If it is about molecular shape of covalent compound, students have to think about which shape for this molecule or other molecules. I ask questions to motivate students' thinking; it helps students to gain long-term memory about such scientific content. The content is quite abstract; students have to imagine the shape they are thinking. I assign them to prepare some balloon, model; this way is very helpful for students' thinking about the shape.
>
> (Reflective journal: January 27, 2010)

It appears that after the PD activities, Tawan was more apparent in linking goals of teaching for CT to her teaching practices. She promoted the students to develop their CT by utilizing students' participation in learning activities such as explaining and drawing a conclusion. She said that, "The students had to draw a conclusion about molecular shape after they had studied progressively more and more complicated molecular shapes of covalent" (Reflective journal: January 29, 2009).

In terms of teaching preparation, after the PD activities, in her interview, Tawan planned classroom teaching based on the nature of content. For example, learning about covalent bonding was difficult for the students because of abstract content; Tawan planned to support students to learn about molecular shape by using balloons and molecular models as instructional media. She also planned ways to draw students' interest and thinking using key questions and an appropriate sequence of classroom activities. Tawan planned to teach covalent bond content such like,

> To launch the lesson, I will motivate them to think about how covalent molecules shape and arrange. They will use balloons to make covalent molecules; they then see how each bond pushes each other. The students also image molecular shapes using provide molecular mode.
>
> (Interview; January 27, 2010)

Preparing assessment was a part of Tawan's planning process. The teacher characterized students' marks using rubric criteria of four scales including excellent, good, moderate, and poor to score students' presentation about Petroleum. This criterion scored students based on doing group work, utilizing of reliable information, organizing information, and presenting their products in several methods. The analysis of this section suggested that Tawan changed in goals of teaching from emphasizing contents and skills in the curriculum to problem-solving skills and CT abilities. She also appeared to plan ways to conduct lessons to develop students' CT.

Classroom Activities

Prior to the workshop, Tawan conducted lecture classes by giving students content knowledge and step-by-step to do experiments, and summarizing key concepts herself. The results based on classroom observation after the PD activities showed that there were changes in the pattern of classroom activities, six classes were observed: comprising five lectures along with additional engaging activities, and one presentation about Petroleum topics. Especially, in lecture classes, Tawan used instructional media, offering the students the chance to solve some chemistry problems within small groups, providing chances for the students to draw their answers on the whiteboard, using open-ended questions. In one lesson of presentation of particular research topics, she allowed the students to plan and design their own presentation techniques.

Throughout lecture classes observed, Tawan encouraged the students to think critically by launching lessons with questions: the students would predict what might be happen based on provided events about repulsive force of molecules. Furthermore, Tawan said in post-class interview where she provided students to discuss and draw with their peers some molecular structures of chemicals that, “Allowing the students to share their understanding and ideas in groups was efficient to promote students’ thinking. For example, the students discussed and indicated polar and non-polar molecules” (Interview: January 29, 2010). This showed that Tawan set a learning activity that motivated students to express their ideas and draw a consensus conclusion together.

Tawan assigned the students to organize presentations based on particular research topics in a learning unit on petroleum. She mentioned that the students experienced how to deal with a huge amount of available information from various resources. To complete the tasks, the students had to plan sub-topics for their groups in order to seek concepts from reputable resources, i.e. textbooks, websites, and persons. As well, they had to design how to present concepts in interesting way. They were assigned to prepare exactly 15 questions related to their presentations in order to assess their peers’ understanding and knowledge gained. Tawan said based on post-class interview that the procedure of doing the presentation required the students to use thinking abilities, i.e. planning work, selecting information and resources, organizing information, designing steps of the presentation, raising questions, and conducting the presentation. These observed teaching practice suggested that Tawan seemed to perceive characteristics of learning activities for CT.

Strategies to Engage Students in Learning Activities

According to classroom observations after the PD activities, Tawan performed various techniques to engage students' learning and thinking. For example, they bound balloons together to display molecular shapes of covalent molecules, and Tawan asked the students to name compounds related to each molecular shape. Then, Tawan used the examples to drive her teaching; she joined models of molecular shapes to describe the arrangement of each bond and angle of the compound. She motivated students' thinking by asking questions which required students' expression of their reasons and ideas. She also encouraged the students to share their thoughts with peers. Teaching polar and non-polar bonds, she wrote two groups of compounds of two atoms for each on the whiteboard; Group 1 composed of H-H, F-F, N-Cl, O=O, and $N \equiv N$ and group 2 composed of H-Cl, F-O, N-O, N=O, and $C \equiv N$. Ms. Tawan asked the students to compare the two groups. The conversation follows:

Ms. Tawan: Look at these two groups of compound; are they the same? (No answers, about 10 seconds), let you think about it, and share your ideas with your friends who sit round you for a minute (some have 2 students, some have 3). (Tawan closed N-Cl in Group 1, and asked students) If I close this compound, what are the similarities or differences?

Students: Types of atom.

Ms. Tawan: How?

Students: Group 1 is the same atoms; group 2 is different atoms.

Tawan: Right. So, what properties make them different? What?

Students: EN

Ms. Tawan: Excellent! What do you mean about EN?

Students: Group 1 has equal EN for each compound, and group 2 is different. (Tawan led students to compare EN for each atom affected the polarity of bonds, and results in polar molecules.

(Classroom observation: January 29, 2010)

Ms. Tawan used the students' answers to drive the lessons. When Tawan taught about polar and non-polar molecules, for example, she asked the students to give examples of bi-atomic molecules (the students named O_2, N_2, H_2, CO, HCl), and then they considered polar bonds in order to make a conclusion about which molecules were polar or non-polar. More complicatedly, the students were asked to give tri-atomic molecules; the students listed H_2O, CO_2, and HCN. In order to answer which molecules are polar or non-polar, the students had to integrate basic knowledge about polar bonds, molecular shape, and vector. The teaching practice suggested to the researcher that Tawan constructed an active classroom. Most of the students replied to her questions and their responses suggested that students were thinking and following classroom activities attentively.

Ms. Tawan furthermore provided her students opportunities to complete provided tasks during lessons. Based upon the lesson of polar and non-polar molecules, Ms. Tawan offered the students the chance to do tasks related to polar molecules after teaching the key concept. The students spent about 10 minutes to point out polar and non-polar aspects of properties10 molecules along with the polar direction for each. Then, Tawan asked for volunteers to give answers and draw out such answers on the blackboard. The students presented collaboratively in answering; there were volunteers for each molecule. But, the last molecule, CH_3OH, presented difficulties for the students. They were not sure about the answer, so there were no answers for this molecule. Tawan challenged the students to try to think about this molecule by giving them a score for all if there was a volunteer. On the other hand, the students would get a lower score in case of no answer. This situation could encourage the students to help each other in thinking about polar of the compound. Some students walked around the class in order to check each other's answers before drawing it on the blackboard. Ms. Tawan liked this lesson, as she stated,

Researcher: How about this your lesson?

Ms. Tawan: I think it is good; but, it will be better if I have more time. However, I observe that students learned about key concepts.

They can give examples of molecules and draw molecular structures in order to identify polar or non-polar molecules.

Researcher: Are there any points to promote students' CT?

Ms. Tawan: They are developing their CT when they participate in activity; they think about molecular shapes, polar direction, and then indicate polar or non-polar molecules.

Researcher: Anything else to promote students to think?

Ms. Tawan: Motivating them; if they try to solve the problem, they will get score for the whole class. These students love grades so much.

(Interview: January 29, 2010)

Challenging the students to do complicated tasks by doing group work, Tawan explained data on melting points and boiling points of different groups of compounds; one group composed of ionic compounds, another a group of covalent compounds. Then, Tawan let the students discuss and compare the melting points and boiling points of a set of mixed ionic and covalent compounds in groups. She also gave ample time for them (about 10 minutes). While the students tried to complete the task by discussing and raising reasons within their groups, Tawan walked around the classroom and gave some information in case the students had questions. Most of them gave reasons for their answers and listened to other ideas, and then they finished the rating of melting points and boiling points of compound within their groups. It appeared that the students were good in active engagement of classrooms.

Questioning Techniques and Treatments of Students' Responses

According to classroom observations after the PD activities, Ms. Tawan used some questions to her students in several ways and relevant to teaching for CT. The nature of her questions appeared to be open-ended questions, whereas almost all of the questions posed in classes before the PD activities were yes-no and short-answer questions and answered by the teacher. In this section after the PD activities, the questions required students' ideas and making decisions were used. For example, during lesson of polar and non-polar molecules, the students named compound of bi-molecules and tri-molecules, then compared similarities and differences between two sets of compound such like, “Now, we have two sets of compound, right? Think and share your ideas with friends, what are similarities or differences observed between these sets of compound? (Classroom observation: January 27, 2010).

During lesson of polar and non-polar molecules, one more an example, she encouraged the students to think about this abstract concept; she assumed one balloon as one molecular bonding. Then, asked her students to predict the arrangement of the balloon after adding one and one more. According to her personal perception of her own practice, she was using more frequent and better questions to promote students' learning as in the second interview; she said,

> …I recognized that I used better and more frequent questions. I attempted to make clear in questioning by repeating or adding some more detail leading the students to consensus understanding. I provide them wait-time to answer, so they had time to think… As we did chemistry activities during the workshop, like the POE, it is necessary to be aware of questioning techniques to motivate students to think and answer to the questions.
>
> (The final interview: January 29, 2010)

Ms. Tawan mentioned that this practice was a result of participating in the workshop; she learned to raise a good question and give enough time for the students to think about the question. She also recognized that the students got better in answering the questions. The students participated more and developed thinking abilities. Tawan said that, “The students made improvements in answering; I also observed that the students spent time to think and shared their ideas with their friends before answering; they were concerned with whether or not they were correct or provided appropriate responses” (The final interview: January 29, 2010).

The finding of Tawan's treatment of students' responses after engaging in the workshop showed that she performed similar to before attending the PD activities. After the PD activities, according to Tawan, it was not good to immediately give the students the right answers whenever they gave wrong ones. She said that, “I did not focus on teaching them only facts or content knowledge. The students should be nurtured to be active and inquiring learners; they must learn how to get knowledge. Though they make a mistake; they gain good experiences from failing” (The final interview: January 29, 2010). As an example lesson of covalent structure, she wrote two groups of compounds, and then asked the students what was different between two groups. She used the students’ responses to drive the lesson as below:

Ms. Tawan: Tell me, how many bonds within a molecule of water? Draw a line structure of water, and count how many bonds it has?

Students: 2

Ms. Tawan: 2 bonds, so what the molecular shape of water should be?

Students: Linear.

Ms. Tawan: Aha, is it linear? Linear, think again, how many bonds?

Students: 2

Ms. Tawan: Okay, 2 bonds, how about its angle?

Students: 90^{o} Oh, nope 180^{o}.

Ms. Tawan: It is 180^{o}, so it should be linear, right? But, in reality, it is not 180^{o}, but it is 105^{o}. Can you tell me why it is 105^{o}, not 180^{o}? What would make it not be normal?

Students: It has lone-pair electrons.

Ms. Tawan: Lone-pair electrons, how do you know that?

Students: Because, um, because.

Ms. Tawan: Because oxygen is in…

Students: Oxygen is in 6^{th} group.

(Classroom observation: January 27, 2010)

It appeared that Tawan did not express that it was bad or wrong if the students gave responses, but she mentioned that students’ responses provided good learning and experience for the students. In addition, she would encourage the students to think critically to learn by their responses (Zohar and Schwartzer, 2005; Perkins and Murphy, 2006).

Cognitive Levels of the Tasks Given to Students

After the PD activities, Tawan gave tasks for the students such as discussing within groups to express their thoughts, solving chemistry problems, making conclusions based on lessons, and searching particular topics and presenting them by each group design. Even though Tawan employed lecture technique in most of her classes, she inserted hands-on and minds-on activities requiring students' engagement, such as using molecular structure models and discussing about chemistry problems in groups based on provided data. For example, ranking melting point and boiling point of a list of provided molecules from lowest to highest, required the students to use various concepts such as bond length, bond strength, and types of molecular forces. They expressed their thought based on task to others; finally they select consensus solutions as an answer of the class.

Seeking to information of particular topics in group work and performing a presentation is relevant to tasks requiring students' CT. Based upon the final interview, it was reported by Ms. Tawan that searching and presenting particular topics would promote students in thinking abilities. As she stated, "…The students had to search and choose accurate information from reliable resources, to organize information and plan how to present the topics in interesting ways… In completion this task, they had to provide 15 related questions for the whole class, these helped them to develop thinking" (The final interview: January 29, 2010). In doing so, it seems that Ms. Tawan employed several of tasks related to promoting students' CT.

Learning Assessment

It was reported on post-class interview after the PD activities that Tawan appeared to think about how to assess students' learning to promote their thinking ability whereas prior to attending the PD activities she focused on assessing students' understanding in content knowledge. Ms. Tawan used performance assessment to assess students' dealing presentation of particular topics in group work. She also mentioned that she examined students' understanding and thinking during her teaching by using questions such as “why” questions. In order to grade the students, major scores still were based upon mid-term and final examinations, and exercises. However, it was reported on worksheets related to chemical bonding concepts and testing documents that the students needed to address their thought and reasons to support their answers inside some written items. It could be said that Tawan was increasing in understanding and assessment practice in assessing students’ learning and critical thinking with Chemistry.

Factors that Influence Ms. Tawan’s Teaching for Critical Thinking

Major factors that influence teaching for CT included the teacher, the students, time, additional school activities, and parents’ expectations. Tawan mentioned that effective teachers should be open-minded persons, and developable persons in their teaching regularly to support the students in reaching their best potential.

> Teachers have to select proper learning activities that motivate their student learning appropriately. They have to recognize that it does not matter only to teach the subject matter; rather the teacher must also promote thinking.
>
> (Interview: January 22, 2010)

Ms. Tawan suggested that students’ background affected her classroom practice. The teacher perceived that there was large gap of student attention between the special science and ordinary science students. According to her interview, the students in the special science class generally concentrated on learning better than another group who had lower average science grades; or who took ordinary science classes. So, she prepared some different teaching and learning activities for different groups of students. As she said, “For the special science class, they are able to learn intentionally though provided learning activities. We have to assign tasks to encourage students’ abilities. Conversely, we might set similar but simpler learning activities for students in ordinary science classes…” (Interview: September 16, 2009).

Another factor was the time constraint, Tawan aimed to complete the subject matter stated in the school curriculum while she faced a limitation of time. At the same time, the school had additional activities that affected class time, so the teacher cannot finish the content with their lesson plans according to the academic timetable. As a responsibility of teaching special science classroom, furthermore, the teacher was forced by students' parents to be a competency teacher. Based upon Tawan's initial interview, some parents called her and questioned the school activities their children had participated in; the parents were not appreciated with some activities without totally concerned with academic content. Sport days activities, for example, took about three days, but the students had to prepare these activities at least a month. Therefore, Tawan decided to pass some cognitive activities engaging students in long time; she used lecturing lessons to solve time constrain problem.

The Teacher's Learning as a Result of Participation in the PD Program

Investigating teachers' changes related to teaching for CT during the PD program is displayed a parallel comparison of teachers' understanding of and teaching practices for CT before and after the PD activities in the following Table 4.1.

Table 4.1 Comparison of Tawan's Understanding of and Teaching Practices for CT before and after the PD Activities

Components		Findings	
		Before the PD activities	**After the PD activities**
Understanding	Meaning of CT	Ability to analytic and classifying thinking, a set of higher-ordered skills	A set of higher-ordered thinking related to reasonable, reflective, analytic, and making decision
	Awareness of teaching for CT	Used in various situations, being to teach for all grade levels via all subjects.	Supporting students in learning, working and living in the present and the future, being to teach for all grade levels via all subjects.
	Identifying teaching for CT	Asking questions requiring reasons, doing scientific experiments	Doing experiments, research and presenting topics, group working, and lecture with doing tasks

Table 4.1 (Continued)

	Components	Findings	
		Before the PD activities	**After the PD activities**
Teaching Practices	Goals of teaching for CT	Developing students in content and scientific skills, academic tests, and thinking	Developing students in solving problems, discussing ability, and CT
	Teaching preparation	Outlining content and activities based on the curriculum	Preparing activities and ways to engage students in learning, and sequence of classroom activities
	Classroom activities	Giving students experiment procedure and leading them to discuss experimental data, and lecturing concepts	Lectures with complicated tasks i.e. predicting what's happening, comparing similarities and differences, and presentation
	Strategies to engage students in learning activities	Using close-ended questions, calling volunteers to demonstrating, reminding students in academic exams	Using students' answers to drive the class, asking questions requiring students' reasoning and ideas, giving scores, and using group-work
	Questioning techniques and treatments of students' responses	Using memorizing questions, answering the questions herself, treating to students' responses by repeating, and move to ask other students	Using closed-ended, and open-ended questions, and providing wait-time for answers, using students' responses to drive the class
	Cognitive levels of tasks given to students	Doing experiments and demonstrating the use of scientific instruments by volunteer students	Asking questions requiring reasoning, discussing in groups, solving chemistry problems, making conclusions, and presenting particular topics
	Learning assessment	Using tests, and doing experiments, grading students by a weighted major mid-term and final tests	Using authentic assessment and performance assessment by examining students' learning during teaching, tests, and tasks

According to data in Table 4.1, it shows that Tawan had improved in her understanding of and teaching practices for CT. She mentioned that CT was a necessary ability for students to support them in learning and lives. Throughout the study, Tawan increased in understanding about teaching for CT. She also was better in linking CT to classroom context. For example after attending the PD activities, she used cognitive questions and inserted cognitive tasks during lecturing lessons. In addition, she appeared to shift her teaching practices related to teaching for CT in several components of pedagogical development of teaching for CT, especially classroom activities, strategies to engage the students in learning activities, questioning techniques, and cognitive levels of the tasks given to the students. She organized and implemented learning activities that appeared to have resulted in more interactive classes. The students appeared more collaborative in learning activities. Taken collectively, the researcher concluded that Tawan was effective at teaching for CT. Further suggests that her changes in practice may have been due to her participation in related professional learning activities on teaching for CT where she shared teaching experiences with others and engaged in solving chemistry problems and design learning activities collaboratively.

Case II: Mr. Artid
A Content-Based Chemistry Teacher

Participant Background

Mr. Artid's background information was drawn from a pre-workshop questionnaire, interviews with the teacher, and classroom observations. Mr. Artid is 53 years old. He is an in-service teacher who has 20 years of teaching experiences. He has taught science subjects for lower secondary students at Namsai Wittaya School for 15 years: the same school as Ms. Tawan. Mr. Artid has 5 years of experience in teaching Chemistry. He graduated with a Bachelor's Degree in Education (specialized in Teaching Chemistry). He also got a Master's Degree in Audio and Visual Education. According to the initial interview with Mr. Artid, he introduced himself as a teacher who had to teach out of responsibility. He said,

> I have not been familiar with Chemistry for many years. I have just taught Chemistry for 5 years. I think, honestly, that teaching them (his students) only to cover all concepts in the Chemistry textbooks is likely impossible. How do I complete so much content? So, I am not concerned about providing a variety of learning activities to them. It seems to waste time.
>
> (The initial interview: August 3, 2009)

In teaching Chemistry, he mostly prepared himself in content knowledge by reviewing textbooks. He said that he was worried about content knowledge because he had not taught Chemistry for many years. So, he had to review the subject matters before entering the class. As he stated in his initial interview, especially, some abstract Chemistry concepts were difficult to teach. He liked to teach concepts related to calculation or solving chemical reactions problems. It was evident from the classroom observations prior to the PD activities that Mr. Artid took a handbook of teaching Chemistry to his classrooms. During the lesson, he regularly switched between teaching students and taking a look at the textbook. It seemed that he lacked confidence in content knowledge and teaching practices. The above information led the researcher to name Mr. Artid as a content-based Chemistry teacher because his teaching appeared only to concern about giving students subject knowledge and reviewing concepts himself.

In the academic year 2009, Mr. Artid taught Chemistry for grades 10 and 11; the average number of students was about 45-50 per class. He had taught Chemistry for two ordinary science classes of 10^{th} grade students; each class had three periods a week. He also had worked with two ordinary science classes for 11^{th} grade students which took four periods a week for each class. In addition, Mr. Artid had taken further responsibility in assessment and evaluation affairs for the school, and had been responsible to administration, a head of a color-team school, and organized additional activities for the science department like science camp outside school. Two years ago, Mr. Artid attended in two professional development trainings: 1) teaching and learning science to enhance students' learning achievement, and 2) using the Internet to design instructional media; they were quite short-term (2 days). Mr. Artid applied his gained knowledge about designing instructional media to do a required classroom action research of the school. He dealt a classroom action research with a class of eight grade students at last year; his classroom action research also showed that the instructional media enabled students to increase their learning achievement. However, he never engages in professional learning activities related to areas of teaching for thinking. He also said that he had no ideas how to teach for thinking. Mr. Artid therefore would like to joy with the research study with his own willingness; he wants to conduct various teaching methods beyond traditional lecturing lessons.

After the researcher informed Mr. Artid about the main goal of the research study was to support the teacher to integrate teaching for CT to practices, Mr. Artid felt interested in the study. He said during the initial interview that he would participate in the study with aiming to enhance his teaching profession and to promote students' CT as well as to create an active Chemistry classroom. However, Mr. Artid still held an opinion hindering teaching for CT that students would develop their CT skills whenever they were ready and intended to do so; not depend on learning activities or the teacher teaching.

Throughout the PD program, Mr. Artid missed several activities provided in the first day of the workshop (see Chapter III). Significantly, this situation might affect his development in teaching for CT depending on the study. It was an important day of experiences which involved examples of Chemistry activities related to teaching for CT. The participants had opportunities to learn by playing role as if they were students who tried to solve and complete cognitive tasks as well as sharing each participant's value teaching experience and thought in the context of teaching for CT. These activities were expected to strengthen the participants' understanding of teaching for CT; then the participants should adapt such understanding into actual classes. In order to support Mr. Artid as much as possible in this situation, the researcher discussed such activities face to face with him.

In order to determine Mr. Artid's teaching practices, the researcher played role as a non-participant observer to observe 10 times of Mr. Artid's classroom practices throughout academic year 2009. Prior to the PD activities, Mr. Artid was observed 4 lessons including: 1) properties of solid, liquid, and gas, 2) solid structure, 3) experiment about properties of gas, and 4) relation of V (volume), P (pressure), and T (temperature). Following the PD activities, his classrooms were observed 6 lessons including: 1) introduction to chemical equilibrium, 2) chemical equilibrium constant (K_{eq}), 3) factors affecting on chemical equilibrium, 4) acid-base theories, 5) dissociation of acid and base, and 6) titration.

Student Background

The researcher was allowed to observe Mr. Artid's classroom practice in an ordinary science class for 47 students in 11^{th} grade. This class also enrolled only female students. In academic year 2009, the students were set into permanent groups of 3 or 4 persons in order to study Chemistry with Mr. Artid; they decided themselves to be a group member. They studied Chemistry in the chemistry laboratory where used by ordinary science students. Generally, they came to the laboratory late because of moving from another room with 5 minutes breaking time among periods. According to observations in earlier lessons, the students sat in groups, and looked very quiet. They rarely presented responses to the teacher. The groups of students who sat in the front of the room displayed responses to the teacher more than other groups. It was reported from a volunteer students' interview that they would like the teacher to create more interesting classes and learning activities. One student said that they liked to study via hands-on activities and doing experiment, rather than sitting and listening to content knowledge as a passive learner. Another student said that she realized Mr. Artid's intention in teaching, but he should use instructional strategies to motivate them to pay attention to lessons such strategies as doing group work, using non-monotone. These students also hoped that they would apply chemistry knowledge into real-life and study in the future.

Classroom Setting

The students' classroom was set as one of two chemistry laboratories for upper secondary students who studied in ordinary science classes. Tables were arranged in nine groups; three rows and three columns. Each group had 6-7 students sitting surrounding the table. The wall was decorated with illustrations and diagrams related to scientific knowledge and school activities. The table of the teacher was located in the front of the room at the middle. There was a LCD projector set for teaching presentations. The whiteboard was located in front of the room. In the back of the room, there was a shelf of some scientific models and instructional media; as well, some basic experimental instruments for each group were put in baskets separately. A washing zone was located on the left hand side; students would clean experimental instruments here before returning them to the same place where they was kept. In addition, it had a small room connected to the classroom used for chemical preparation and keeping some scientific instrument as Figure 4.3

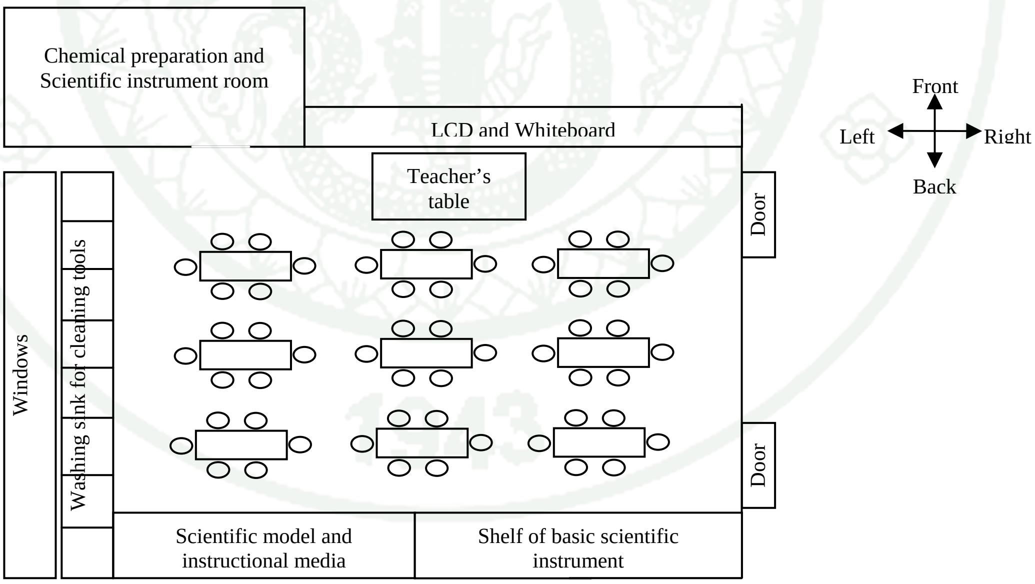

Figure 4.3 Layout of Chemistry Laboratory of Grade 11

Findings about Mr. Artid's Teaching for Critical Thinking

The following sections discuss the findings regarding Mr. Artid's understanding of teaching for CT and teaching practices for CT prior to the PD activities. Then, the discussions pay attention to how the teacher changed his teaching techniques as the results of participating in the PD activities.

The Findings before the PD activities

Understanding of Teaching for Critical Thinking

The analysis of Mr. Artid's understanding of teaching for CT was drawn from a questionnaire and interviews. At the beginning of the study, Mr. Artid defined CT as an ability to give reasons to support answers. According to the initial interview, Mr. Artid said that CT was a very important ability for students in studying all subjects. It enabled students to reason and calculate Chemistry problems. However, Mr. Artid held beliefs that were considered barriers to the development of the students' CT. He said that teaching for CT did not depend on teachers or learning activities—only students were the key persons. So, he overlooked to create classroom environment that would encourage students to learn. Mr. Artid said that different learning activities did not produce different learning outcomes. All activities enabled students to think critically. He also said that asking questions and solving Chemistry problems were good ways to promote students' CT.

> Critical thinking is giving reasons why you (the students) present or answer like that. The answer might be wrong or right—but what are the reasons? To develop students in CT, the major factor is students themselves. Do they intend to develop their thinking ability?
>
> (The initial interview: August 3, 2009)

Although he mentioned about the importance of teaching for CT in the interview and the questionnaire before the PD activities, in practice, he focused on developing students' content knowledge. The learning objectives indicated in his lesson plans were all related to nurturing students in content knowledge and scientific skills. Based on his response to the question about the factors affecting teaching for CT in the questionnaire, Mr. Artid indicated that implementing CT activities in class took too much time and might not be worthwhile. More importantly, he reported in the initial interview that he did not know how to teach for CT even though he would like to teach for CT. Eventually, he used lecturing approach and gave students some exercises based on Chemistry textbook. Mr. Artid believed that assigning as much exercises in the textbooks to students as possible helped them develop their CT. It could be said that Mr. Artid had limited knowledge about the meaning of CT. He also lacked understanding about how to teach Chemistry and promote students' CT at the same time. Mr. Artid further talked about his students in the initial interview that the students in this class were considered low-academic achievers than the students in the special science program. Hence, his students seemed to be quiet and inactive, compared to the students in the special science program. So, he said learning activities and complicated tasks were too difficult for his students to complete.

The analysis of Mr. Artid's prior understanding about teaching for CT before attending the PD activities suggested that Mr. Artid knew very little about the definition of CT and how to incorporate teaching for CT in Chemistry. He also held some opinions that seemed to obstruct teaching for CT, such as the belief that his students would not be able to handle complicated learning activities and the belief that using CT activities was a waste of time and took too long to complete.

Teaching Practices for Critical Thinking

In order to analyze how Mr. Artid conducted his classroom in the context of teaching for CT before attending the PD activities, the researcher used valuable information from the classroom observations, the interviews, as well as his teaching materials. The following sections present Mr. Artid's teaching practices which were categorized into goals of teaching and teaching preparation, classroom activities, strategies to engage students in learning activities, questioning techniques and treatments of students' responses, cognitive levels of the tasks given to students, and learning assessment.

Goals of Teaching and Teaching Preparation

The result was drawn from the questionnaire and the interviews before the PD activities in order to know Mr. Artid's goals of teaching and how he prepared for his classes. At the beginning of the study, Mr. Artid held explicit beliefs about teaching for covering content knowledge. He intended to develop students' understanding about key concepts in Chemistry in order to pass examinations. According to the post-class interview with Mr. Artid, he said that he wanted his students to be able to calculate Stoichiometry and the changing states of substances (gas, liquid, and solid). He also believed that if students could solve chemical problems, then they were involved in thinking development. Consistently, the learning objectives in his lesson plans mostly aimed to nurture students' subject knowledge and experimental skills. He said, "First, I want to teach them to understand key concepts. If they are able to calculate, they are thinking. However, I do not think about how to teach them to think critically" (Interview: August 26, 2009). He believed that learning Chemistry required students' understanding about scientific facts and knowledge. In the post-class interview, Mr. Artid said that,

> There are too many concepts to teach them. I skip experiment sessions when we have many teaching concepts left. I will summarize the experimental procedure and results to them by focusing on key concepts. After that, I come back to the concepts to explain and give more details if we have time.
>
> (Interview: September 16, 2009)

It appeared that Mr. Artid's major goal of teaching was to develop students' understanding in scientific knowledge. He seemed not aware of promoting students' CT. He also perceived that his responsibility was to cover content knowledge only. This traditional lecturing method was considered ineffective in promoting students' meaningful learning and thinking abilities (Chiu, 2005; Juntaraprasert, 2009).

Analyzing how Mr. Artid prepared his class was based on the initial interview and the questionnaire. Mr. Artid reported that he spent time on reviewing knowledge in the Chemistry textbooks whenever he had free time. It could be said that he rarely designed learning activities and tasks beyond the textbooks because he intended to cover the concepts indicated in the school curriculum by lecturing method. Even though Mr. Artid spent a lot of time reviewing the concepts, it seemed not enough to assure his adequate performance in class. During a class observation before the PD activities, Mr. Artid brought a Chemistry textbook into the class as a key material in his teaching. He walked to the textbook many times and spent a few minutes to look at the concepts in the textbook before explaining how to solve some Chemistry problems step-by-step. Mr. Artid also held some beliefs that possibly hindered teaching for CT as follows:

> It is hard to prepare and use CT activities, especially with secondary school students who have to focus on subject knowledge. Teachers also have to be an expert in subject matters so that they can design appropriate activities.
>
> (The initial interview: August 3, 2009)

The above results of Mr. Artid's goals of teaching seemed to influence his teaching preparation. He aimed to teach students as much content knowledge as possible, so he only made sure that he had correct understanding about the concepts before giving a lecture. The classroom observations suggested that Mr. Artid did not plan for an experiment even though he said that he aimed to promote students' scientific skills through conducting experiments. For example, during the setup of a laboratory on gas's volume and pressure, he read the laboratory directions quickly. He also told his students that, "Actually, I intend to pass this activity (V and P of gas). However, after I read its procedure, I felt it was not complicated and used only short amount time. So, we will do it" (Classroom observation: August 26, 2009). Then, he asked students to read the instructions quickly before the lessons started while he was preparing the chemicals and instruments for the experiment. They did not plan to do the experiment before. Those findings suggested that Mr. Artid was not concerned about preparing learning activities to create active and engaging classrooms. He just let students do the experiment following the textbook. He also mentioned clearly that he had never been concerned about developing students' CT before, although he realized the importance of CT to students' studying and living in the real world. Therefore, the analysis of this section suggested that Mr. Artid did not intend to develop students' CT along with subject knowledge. He also focused on preparing himself before teaching.

Classroom Activities

The classroom activities conducted by Mr. Artid before attending the PD activities showed that he played a major role in class and he was an important source of knowledge. He taught students by explaining how to solve Chemistry problems. For instance, during a calculation of chemical reactions, he began by talking about the relation of some chemical reactions followed by telling students how to solve a problem related to chemical reactions step-by-step. During a classroom observation, while the teacher was describing about a concept, students did not pay attention well. Mr. Artid said in the post-class interview that he should improve students' interaction in classroom activities. He also said that one problem in his teaching was a relationship between he and his students. They did not pay much attention to each other. The class was observed while Mr. Artid was lecturing and asking students some questions. The students appeared to have a few feedbacks or answers to the questions. The students who sat in the front of the room gave more responses to the teacher than the other students who sat in the back.

In an experiment session, Mr. Artid explained steps of the experiment to be conducted briefly, and then he let students conduct the experiment in groups, while Mr. Artid was walking around the class and giving students some suggestions related to the experiment. After finishing the experiment Mr. Artid led students to conclude the lesson. Below is a sample conversion in class, after finishing the experiment on allotrope of rhombic and monoclinic sulphur.

Mr. Artid: Okay, which groups has got rhombic? Rhombic sulphur?
Students: (No responses from the students).

Mr. Artid: No group has got it, I guess. Do you know why? Why?

Students: (No answers from the students).

Mr. Artid: Because, we took too little time. Actually, we have to wait longer to get rhombic sulphur. We have to allow it to crystallize slowly. Do you know another reason why? It might be that we add too much sulphur powder and it is a strong concentration solution. We have to spend a long time to get it. That's why every group just gets monoclinic sulphur.

(Classroom observation: August 10, 2009)

After describing the concepts, he spent a few minutes to read the next topic in the textbook before teaching that content. At the end of the lesson, he assigned students to complete some exercises in the textbook. In the initial interview, Mr. Artid stated that if students did as many exercises as possible, then they would increase their thinking ability. It appeared that Mr. Artid conducted classroom activities following traditional teaching approach, in which students were passive learners who listened to the teacher's talking or did experiments as if following a cookbook. This teaching approach is seen as a barrier in teaching for CT (Zohar and Schwartzer, 2005).

Strategies to Engage Students in Learning Activities

The findings from the classroom observations at the beginning of the study suggested that Mr. Artid overlooked pedagogical practice to engage students in learning activities. He stated in the initial interview that it was enough for students' learning if teachers just described content knowledge to students. Mr. Artid taught following the content in the textbook. He said after teaching about chemical reactions, "They (the students) have little participation. They rarely respond and only listen to me. They are quiet. Therefore, I present them how to solve Chemistry problems step-by-step" (Interview: August 26, 2009). In experiment sessions, students were less involved in the scientific inquiry. For example, to investigate a relationship of gas pressure (P) and gas volume (V) based on Bolye's Law, Mr. Artid prepared materials for the experiment, while students were reading the instructions. He briefly explained about the experimental procedure along with demonstrated how to use some instruments. Within the same group, some students were doing the group's tasks while the others did not help. Students did not get to discuss and plan how to conduct the experiment before. Finally, Mr. Artid acted as a leader in drawing conclusions about the experiment. He asked for the experimental results from students. Then, he compared them to the data in the Chemistry textbook, which was used for concluding. Mr. Artid did not use the students' results to drive classroom discussion. Those findings suggested that Mr. Artid lacked strategies to engage students' attention in classroom activities. This might limit the teacher's ability to teach for CT. It appeared that the students did not discuss or reflect their understanding based on the experiment. They only followed the laboratory instructions. They were not challenged to inquiry-based investigation as much as they should. Finally, the students might not promote CT as much as they should.

Questioning Techniques and Treatments of Students' Responses

According to the initial interview and the questionnaire before attending the PD activities, Mr. Artid said that asking student questions was a good way to promote students' critical thinking. In earlier observations, Mr. Artid used a few questions comprising of yes-no questions, close-ended questions, and short-answer questions. For example, while he was teaching about the states of substances using lecturing method, he asked questions in the following way:

Mr. Artid: Do you know why Naphthalin changes from solid to gas state? (No students' responses) That's because it has weak bonding force, so molecules can be broken from each other easily. What is a factor that affects this change?

Students: Temperature (An answer from a few students).

Mr. Artid: Yes, temperature. Heat is the factor. Heat causes increasing energy of molecules, so that's why Naphthalin changes its state.

(Classroom observation: August 26, 2009)

For almost every question that was asked, Mr. Artid did not encourage students to discuss about the questions. Nor did he use other methods of asking, such as calling individuals, pairs or groups to answer. The observations showed that only a few students responded to some questions. Most of the questions were answered by the teacher--sometimes, immediately. He did not use what students answered to follow their understanding. Throughout the observations before the PD activities, there were a few times when he used words or phrases which encouraged students to think, such as “Do you know why…?”, “Solve this problem within your group.”, and “What will happen if molecules become strongly vibrated because of heat?” He provided only little time to answer or to solve the problems.

According to the classroom observations at the beginning of the study, class time was mostly spent on the teacher’s lecture. It appeared that students practiced improper behaviors in the class, such as not responding to the teacher, doing works of other subjects, being late to class, and being unaware of safety during an experiment. The observations showed that Mr. Artid tended to ignore those students’ behaviors. He did not remind or suggest them to improve themselves. He just came to class, and then, talked about the concepts he planned to teach. Students’ responses were also ignored or rejected immediately.

To give feedbacks to students’ answers, Mr. Artid said “Yes” if they were right and “No” if they were wrong followed by Mr. Artid’s correct answers immediately. He said that, “It was not a big problem whether the students gave right or wrong answers, but I just wanted them to say something about their thoughts” (Interview: September 16, 2009). Mr. Artid assigned the tasks in the textbook to students for homework. He checked whether students did it or not, without correction. This practice seemed to be inappropriate to promote students to think critically as much as possible. So, students were not engaged in learning activities that motivated thinking, which relied on reflective thinking and reasoning to develop their CT.

Cognitive Levels of the Tasks Given to Students

Throughout the first semester of academic year 2009, the researcher examined the teacher's tasks, lesson plans, and worksheets related to the lessons observed. The findings revealed that most of the tasks that Mr. Artid provided for students were exercises in the Chemistry textbooks as homework. There were no further worksheets constructed for students. The tasks in the textbooks generally required students' understanding and thinking abilities to complete them. The findings before the PD activities suggested that Mr. Artid had limitation in taking advantage of the tasks to promote students' CT. He just assigned students to do the tasks, but did not correct them, or challenge students to discuss about the tasks with the whole class. Students would not know whether they were right or wrong. Also, students might not know how to solve such exercises. In addition, for scientific experiments which were supposed to enhance their abilities in scientific investigation and CT, the students only checked step-by-step instructions in the textbook to conduct the experiments. They were not engaged in reflection or discussion after the experiments which were supposed to develop reflective thinking and reasoning. These teaching practices suggested that Mr. Artid provided high cognitive tasks for his students, but he did not use such tasks adequately to promote students' CT.

Learning Assessment

The details of how Mr. Artid assessed students' learning before the PD activities were drawn from the interviews, teaching materials, and examinations. Mr. Artid emphasized assessment of content knowledge based on school curriculum to evaluate his teaching goal. Mr. Artid examined students' knowledge after he finished teaching concepts using tests. The tests were open-ended items requiring students' understanding in both basic and applied knowledge. For midterm and final examinations, all test items involved four multiple choices. Most of the items seemed to be difficult. To solve some items, students had to do two or three steps. However, the tests are difficult to prove how students think and solve problems.

Based on the initial interview, he also observed students while conducting experiments, but he said that he did not use the observation to grade them. He only checked students' experimental reports to grade them. The students' learning was evaluated by using paper tests before and after midterm examinations, midterm examinations, and final examinations. Paper tests were one valuable method to investigate students' CT in the case of productive design and implementation (UMUC, 2006). Mr. Artid reported in the initial interview that he never assessed students' CT, and never thought about it. Therefore, Mr. Artid wanted to learn how to assess students' CT in Chemistry. The analysis in this section suggested Mr. Artid focused on assessing how much students understood about content knowledge. He was not aware of examining students' CT ability in Chemistry.

The Findings after the PD activities

Understanding of Teaching for Critical Thinking

The analysis of Mr. Artid's understanding of teaching for CT after the PD activities was drawn from interviews and group meetings. Mr. Artid presented gradual change in his understanding about teaching for CT. Mr. Artid gave a more-detailed definition of CT and gave more examples of teaching for CT in Chemistry, compared to his statements before the PD activities. Mr. Artid emphasized the importance of CT for students during group meetings. He stated that CT was very helpful for students' learning, especially in science. Teaching for CT, therefore, should be integrated into all classrooms. He also mentioned about his teaching after the PD activities that he considered more about learning activities that would promote students' CT. Furthermore, he was more aware of learning activities for CT and characteristics of a critical thinker. In the final interview, he said, "CT involves reflective thinking and reasoning in solving Chemistry problems. Therefore, a critical thinker is a person who is able to solve Chemistry problems, especially the problems related to calculations and chemical reactions" (The final interview: January 20, 2010). Those evidences suggested that Mr. Artid had a deeper understanding about teaching techniques for CT. He stated about how to improve his teaching practices to correspond to teaching for CT, as follows:

> Um, students seemed to pay more attention and perform better in answering questions. It is a good thing that when they calculate, they do a good job. They answer collaboratively. Actually, I should call them to write on the whiteboard. It might take some time, but it will let me know what they learn or understand. Next time, I will call on them to answer.
>
> (Interview: December 21, 2009)

Mr. Artid also mentioned that his power point presentations supported students' learning and thinking abilities. He said in the post-class interview after the PD activities that he should make more interesting power point presentations by adding pictures or animations of chemical reactions. He also reflected in his journal during the PD program that, "I realize that I am better in teaching practices (compared to my teaching before). After participating in the PD program, I have learned that teachers should motivate students to think critically by allowing students to work in groups, using questions, and engaging students in experiments and solving Chemistry problems" (Reflective Journal based on the PD program: February 4, 2010).

According to the above statements, Mr. Artid had improved his understanding about CT and teaching for CT, compared to the beginning of the study. He perceived CT as reflective and reasoning abilities to solve Chemistry problems. He also gave more examples of learning activities that supported students' CT in learning Chemistry. Furthermore, Mr. Artid seemed to shift his opinions that teachers could incorporate teaching for CT into Chemistry subject, whereas he said in the initial interview that it was difficult to teach for CT. He also did not talk about covering content as much as possible as he stated at the beginning of the study. These evidences suggested that Mr. Artid had improved in understanding about teaching for CT after attending the PD activities.

Teaching Practices for Critical Thinking

Goals of Teaching and Teaching Preparation

The findings from the interviews and reflective journals after the PD activities were utilized to support analysis of Mr. Artid's goals of teaching and teaching preparation. The results in this section showed that Mr. Artid appeared to be aware of teaching for CT. He emphasized during a group meeting that students in all levels should engage in learning activities that promoted thinking for all subjects. He also addressed in the final interview that how he planned to teaching in order to promote students' CT in Chemistry. As he reported, "I prepared for teaching more than I ever did; I think more about learning activities. I would like to motivate them to think critically and use reasoning. If we (teachers) provide activities for them, they will develop their thinking" (The final interview: January 20, 2010). It appeared that Mr. Artid realized an important role of teachers in developing students' CT whereas as opposed to, before the PD activities, he held belief that students could develop their CT on their own if they were ready and wanted to do it.

The findings from the interviews with Mr. Artid and his teaching materials illustrated that Mr. Artid still focused on preparing content knowledge by reading Chemistry textbooks. But he also planned how to present the concepts. He jotted down learning activities for the concepts, which he did not do in the first semester. He also searched on the Internet for further information aside from the textbook. He also got and adapted some instructional media from the Internet to use in his classes. He said that he aimed to develop students in scientific skills and thinking abilities. Furthermore, Mr. Artid used quizzes to assess students' knowledge before and after each lesson. The quizzes involved open-ended items, which were helpful in motivating students to think critically. An analysis of Mr. Artid' goals of teaching and teaching preparation suggested that Mr. Artid seemed to intend to employ greater teaching practices for CT.

Classroom Activities

The findings of Mr. Artid's classroom activities in this section were based on classroom observations and an interview after the PD activities. It seemed that Mr. Artid employed more various classroom activities than he did in the first semester, in which there were only lectures and scientific experiments. Mr. Artid's the observed classroom activities following the PD activities were improved such as using lectures along with asking students to solve Chemistry problems, using quizzes before or after lessons, and doing experiments. Mr. Artid stated in the final interview that, "I think I have better feeling in teaching this class. The classroom environment is better. The students have movement and responses. I think because I give them some activities like solving Chemistry problems with their group members and asking them to present their solutions to the whole class" (The final interview: January 20, 2010).

Mr. Artid began lessons with quizzes or asking about natural phenomena. For example, in the lesson about the equilibrium state, Mr. Artid asked students to think and give examples of natural phenomena, which led the class to discuss physical and chemical changes. The classroom observations showed that the number of students who responded to questions increased, comparing to before the PD activities. The observed findings also suggested that Mr. Artid used various techniques to summarize the lessons, such as calling some students to conclude a concept for the other students, and then, he emphasized key concepts of the lessons and assigned them to do exercises based on the textbook. Therefore, the analysis of classroom activities after the PD activities conducted by Mr. Artid suggested that he had improved his classroom activities. He used tasks and activities that required students' participation and thinking. He also increased interactions in the class, whereas they seemed to be quiet at the beginning of the study.

Strategies to Engage Students in Learning Activities

The results from the classroom observations after the PD activities illustrated that Mr. Artid had gradually improved in engaging students in learning activities using a variety of techniques, such as asking questions with longer time to think for the answers and calling individual students to answer his questions. It appeared that Mr. Artid seemed to be more aware of how to engage students in learning activities. He said, “I saw that the students pay more attention to me and answer my questions, not as quiet as before. Thus, in the next lesson, I will motivate them further. I should call individuals or groups to answer. I also will give them a Chemistry problem, and then, let the students solve it together” (Interview: December 21, 2009). That statement suggested that Mr. Artid had shifted from the idea that only students were key factors to students’ improvement in learning and thinking to the idea that teachers, students, and learning activities are equally important to teaching for CT. In practice, Mr. Artid also encouraged students to share their ideas while solving problems of dissociation of acid and base in groups. After spending a few minutes to complete the task, each group gave a presentation to the whole class.

In addition, Mr. Artid assigned the class to do titration experiments. He informed students to study and plan a procedure of acid-base titration based on the textbook before they started the lesson. Mr. Artid also gave steps of the experiment for the whole class as well as raising each chemical up (NaOH, HCl, and Phenolphthalein) to remind the students about the bottom of each chemical (at the counter in front of the rooms). He also demonstrated techniques of using pipette and burette to the class. It was observed that the students appeared to be active in doing the experiment and almost all of the group members helped their groups to complete this task. During the experiment session, Mr. Artid observed and asked students to predict what might happen if they did the next steps. Using quizzes also seemed to motivate students’ interest in the lesson. They would talk about the quizzes and ask the teacher about some items. It was observed that students did not do the tasks from other classes during the lessons as they used to do at the beginning of the study.

Questioning Techniques and Treatments of Students’ Responses

After attending the PD activities, Mr. Artid appeared to improve in using open-ended questions and other questioning techniques. The findings from the classroom observations suggested that Mr. Artid used both closed-ended and open-ended questions, which some of the questions required reasons or ideas to support them. Based on the final interview, Mr. Artid said that, "While I was describing content knowledge, I might use questions to follow students' understanding on what was taught and to engage them in the lessons. The students responded better to the questions" (The final interview: January 20, 2010). This result was also supported by the findings from the classroom observations. It appeared during the observations that Mr. Artid used a variety of strategies to challenge his students to answer questions, such as providing suitable wait-time for thinking, re-asking or asking easier related questions, calling on individuals and groups, and using eye contact with students. For example, when he taught about chemical equilibrium, he motivated students to think by asking something like "Observe this graph, and then tell me what you think about it, tell me, what's happening to the concentration of reactant and product over a longer and longer period time?" (Classroom observation: December 21, 2009). While doing experiments, Mr. Artid used questions to encourage students to think about why they did each step before the students started the experiments.

The results from the classroom observations after the PD activities suggested that Mr. Artid showed a small improvement in using techniques to give feedbacks to students' responses. He still ignored and rejected wrong answers immediately as he did before the PD activities. However, he paid more attention to students' responses and answers by spending a few second to think about the students' answers, and then, asked the students for reasons to support their answers. Mr. Artid illustrated good body language to respond to students' answers, such as smiling and looking at the students who were wrong, and then, repeated such answers and asked for some other answers. Finally, he hinted the class which answer was to be selected as a final answer. Mr. Artid also praised the students who gave correct answers by saying "That's right." or "Excellent". He assigned students to answer exercise items in the textbook in groups. This strategy promoted collaborative learning and encouraged students to express their reasoning with each other. For example, in an experiment session, in which students conducted acid-base reaction and titration, some of them performed some steps incorrectly, such as using the same dropper for different solutions without cleaning. Mr. Artid saw that and used questions to guide them. He asked how it would affect the results of the experiment. He also used the results from each group to motivate them to discuss about the factors influencing different findings. Therefore, the analysis in this section suggested that Mr. Artid had improved in questioning techniques and treating students' responses in a way that promoted students' CT.

Cognitive Levels of the Tasks Given to Students

After attending the PD activities, Mr. Artid prepared a wider variety of tasks for the students. He still assigned students to do exercises in the textbook as a major task. However, he provided further tasks, such as worksheets, solving problems in groups, solving Chemistry problems on the whiteboard, and doing experiments. Mr. Artid had progressed in providing and implementing tasks that promote students' CT. For tasks in the textbook, Mr. Artid assigned students to do some tasks in the order of level of difficulties, from the easier ones to the harder ones. However, he just checked whether the students did it or not. He showed the solution of difficult items to the whole class later. Mr. Artid allowed students to conduct titration experiment and discuss about the experimental results, which would promote students' scientific skills and CT abilities. The students looked active while doing it. They tried to titrate to get to the equilibrium point of reaction by slowly dropping the solution, while the titrated solution was changing color slightly. Mr. Artid encouraged students to think critically by leading them to calculate the concentration of the solution based on their results. He then motivated students to find out the reasons why they got different results from each other. At the end of the lesson, Mr. Artid also gave a similar titration problem to students to solve individually. The findings in this section suggest that Mr. Artid was better, to some extent, in providing tasks for promoting students' CT.

Learning Assessment

The findings before the PD activities showed that Mr. Artid focused on assessing students' understanding about the content knowledge they have learned. He mostly graded students using paper-and-pencil examinations. The data from his interviews after the PD activities showed that Mr. Artid implemented multiple assessment methods. The first new thing was using quizzes before or after lessons. Some of the quiz items required exact and short answers, and the others can be completed by writing long answers, solving problems step by step, and expressing ideas or suggestions. Those items appeared to promote students to think critically to answer them. Moreover, he said in a post-class interview that he examined students' CT by observing them while they were solving a Chemistry problem with peers and presenting it to the whole class. It seemed like Mr. Artid believed that he was able to assess students' CT in Chemistry, which he said he never thought about before the PD activities. As he said, "I just realize that learning activities are very important to develop students' learning. They can solve difficult tasks within the limited time" (The final interview: January 20, 2010). During experiments, Mr. Artid also observed what each group did and gave some suggestions. He also assessed students on group working, experimental reports, and tasks completion after the experiment. The findings from data analysis of this section implied that Mr. Artid improved his assessment practices for CT in Chemistry.

Factors that Influence Mr. Artid's Teaching for Critical Thinking

In order to investigate important factors that influence Mr. Artid's teaching for CT, the researcher used a questionnaire, interviews with the teachers, reflective journals, and classroom observations throughout the study. The results from the data analysis suggested that four affective factors that influence Mr. Artid's teaching for CT included the teacher (Mr. Artid), students, time, and school facilities.

Regarding the teacher, which was Mr. Artid himself, his understanding about teaching for CT and his goals of teaching seemed to affect Mr. Artid's teaching for CT. At the beginning of the study, Mr. Artid believed that all learning activities served to develop students' understanding and CT as long as the students were ready to develop their thinking abilities. He felt that different learning activities would not produce different results. So, he was not aware that he was a key person in creating a productive learning environment. Thus, he just taught them what scientific concepts he wanted them to learn. Mr. Artid decided to participate in the study in order to learn how to teach with new teaching approaches (i.e. student-centered teaching and learning approach) that emphasize the promotion of students' thinking abilities because, in his perception, he had a few years of teaching experience in Chemistry. He would like to change and enhance his own competency in teaching. However, he never engaged in a long-term professional development program prior to this PD program. Mr. Artid said that he was not used to thinking about teaching for thinking. Rather, he wanted to develop students' knowledge in science in order to pass academic examinations and national academic competitions. Therefore, he spent most of his time on studying the content knowledge. He conducted his lessons before attending the PD activities following content-driven classroom, with no concerns about practices in the context of teaching for CT. However, the findings after the PD activities suggested that Mr. Artid had improvements in teaching for CT. He could link his goals of teaching for CT to classroom related to teaching for CT. Thus, it could be said that Mr. Artid's understanding about teaching for CT affected how he conducted actual lessons in the context of teaching for CT. Therefore, it could be inferred, in the case of Mr. Artid, that the teacher was one factor that affect his own teaching practices for CT.

Students also played a role of an influencing factor in teaching for CT. According to the interviews with four volunteer students about their Chemistry class, they said that they only had a few experiment lessons. They said that doing tasks or exercises based on the textbook was a good teaching method, but they were bored sometimes. The students asked for more different learning activities to be provided to them. However, they mentioned that the teacher was better in providing learning activities. During lectures, the teacher had some activities that required their participation. The classroom environment looked more suitable for students' learning development, compared to the observations before the PD activities.

Time was also a key factor that Mr. Artid mentioned. In order to conduct learning activities related to teaching for CT, it usually took more time, while the students were expected to cover a huge amount of subject matters in the school curriculum. Teaching concepts to students was easy to manage in a limited amount of time. Mr. Artid said that it was a waste of time to engage students in cognitive learning activities. He did spend some time on such learning activities to convey the concepts, but he always gave them up whenever he faced time constraints, and then, he only gave lectures on the key concepts. However, Mr. Artid demonstrated an attempt to organize his time because he wished to increase his skills in conducting classroom activities to promote students' CT.

The last factor was additional school activities. This factor might have affected Mr. Artid's teaching a bit. Mr. Artid said that the school normally set time period for teaching Chemistry, which seemed to be enough to allow students to do cognitive learning activities. Yet, in practice, it was not possible for the teacher to use an entire period to teach Chemistry. The time had to be shared with other school activities.

The Teacher's Learning as a Result of Participation in the PD Program

In order to investigate the effect of the PD program on Artid's changes in understanding of and teaching practices for CT based upon the essential pedagogical development of teaching for CT are compared in Table 4.2 as below.

Table 4.2 Comparison of Artid's Understanding of and Teaching Practices for CT before and after the PD Activities

Components		Findings	
		Before the PD activities	**After the PD activities**
Understanding	Meaning of CT	Ability to give reasons for answers	Ability in reflective thinking and reasoning
	Awareness of teaching for CT	Support students in calculation about chemistry problems	An important ability in learning for all subjects, like solving chemistry problems
	Identifying teaching for CT	Solve chemistry problems, and doing exercises in textbooks	Doing experiments, solving problems, and doing exercises about the content

Table 4.2 (Continued)

	Components	Findings	
		Before the PD activities	**After the PD activities**
Teaching Practices	Goals of teaching for CT	Developing students' knowledge of content, and doing examination	Developing students' knowledge of content, active interaction in classroom
	Teaching preparation	Contents, and experimentation	Contents, learning activities, and instructional media
	Classroom activities	Teacher talk, doing experiments	Teacher talk, doing experiments, engaging students in cognitive tasks
	Strategies to engage students in learning activities	Asking questions, and doing experiments	Asking questions, encouraging students in discussing with peers, and solving chemical problems
	Questioning techniques and treatments of students' responses	Using memorizing questions and answered by the teacher. Most words were related to teaching concepts, ignoring some wrong questions, and correction by the teacher	Asking questions requiring reasons, re-asking and adding similar questions; calling on individuals and groups, asking other students, and encouraging the class to find the answers
	Cognitive levels of tasks given to students	Using tasks requiring basic concepts based on the textbooks	Using tasks with difficulties from basic to more complicated, such as solving chemical problems, and doing experiments
	Learning assessment	Using summative assessment by paper and pencil tests	Using tests of concepts before teaching, doing experiments, and paper and pencil test

In conclusion, as the summary shown in Table 4.2, in order to answer the first research question: What are the participating Chemistry teachers' prior understanding and teaching practices for CT? Mr. Artid had a narrow view of CT. He defined CT as an ability to give supporting reasons for answers. Mr. Artid illustrated better understanding on the meaning of CT during his participation in the study. He perceived CT as higher-order thinking which referred to reflective thinking and reasoning skills. He mentioned that teaching for CT involved using questions that required supporting reasons, and solving Chemistry problems based on the textbook. In a later interview, Mr. Artid characterized teaching practices for CT as practices that engaged students in classroom activities, such as doing experiments and using students' answers to drive the class. He was better in planning for teaching for CT. The findings also suggested that Mr. Artid's gradually organized classroom activities in accordance to teaching for CT throughout the study. He continuously increased the use of CT questions and classroom activities related teaching for CT. Therefore, it could be said that the PD program was very helpful in enhancing Mr. Artid's understanding and teaching practices for CT.

While working with Mr. Artid, the researcher learned that there were two main factors related to the teacher's learning, including the teacher and his students. According to the background of the teacher, Mr. Artid did not say that he taught purposively for CT. He only intended to create a better classroom environment to develop students' learning. Thus, a teacher who attempted to develop students' CT as a motivation had a greater driving force to learn how to teach for CT than the ones who did not. Teaching experiences also affected the teachers' development. Mr. Artid perceived that he had little experience in teaching Chemistry. Therefore, he was still worried about content knowledge. This led him to be less confident in subject matters, which made it difficult to design and conduct lessons in a suitable way. In Mr. Artid's opinion, students were also considered a key factor in teaching for CT. Those students wanted the teacher to create more active classes. They showed little attention and few responses to transmission of knowledge teaching approach. However, Mr. Artid's teaching development across the study was considered satisfactory in the context of teaching for CT.

Case III: Ms. Ratree
A Novel Chemistry Teacher

Participant Background

The background information of Ms. Ratree's was drawn from pre-workshop questionnaire, interviews, and classroom observations. Ms. Ratree is 30 years old and has been an in-service Chemistry teacher at Tonnam Suksa School for 3 years. Therefore, the researcher named her as a novel Chemistry teacher. Ms. Ratree received a Bachelor's Degree in Education (specialized in Teaching Chemistry). Throughout the academic year 2009, she taught science subjects for three classes in grade 8 and Chemistry for two classes in grade 12. There were 35-40 students per class. This study investigated Ms. Ratree's teaching in a class of thirty six grade-12 students. Beyond teaching, the teacher was responsible for assessment and evaluation affairs, and also, scientific extracurricular activities in the Department of Science. Since 2007, the teacher had experience in attending workshops related to creating instructional media using information communication technology [ICT]. She applied that knowledge to design instructional media in her classrooms. She presented what she aimed to teach students with an LCD projector, and sometimes, presented animations of chemical reactions. She seemed familiar with her students, which suggested that they had a good relationship with each other.

In order to convince Ms. Ratree to participate in the PD program, the researcher introduced the scope of the PD program, which showed how it would be helpful for Chemistry teachers; she was interested in the PD program. Ms. Ratree stated that she intended to improve her teaching competency and teaching profession. Therefore, participating in professional learning activities was a good opportunity for her. Moreover, at that time, the school she worked at was actively promoting teachers' development in using instructional media with ICT in classrooms and encouraging students in higher-order thinking. After Ms. Ratree learned about the goals and activities of the PD program, she decided to attend immediately. She said,

> In fact, last year, the school emphasized teachers to teach for higher-order thinking. For this year, we were concerned with designing instructional media which was expected to support students in learning and thinking. I think this PD program will be very helpful for me. A whole year of participation will enable me to make some changes in my teaching as well as encourage me to pay more attention to teaching.
>
> (The initial interview: August 4, 2009)

According to the above statement, the researcher assumed that the teacher was willing to participate in the PD program. Therefore, she was expected to do her best in completing the learning activities and tasks the PD program offered her. Working with Ms. Ratree, the researcher observed her classroom practices for ten times. Before attending the PD activities, she was observed four times while she was teaching the following topics: 1) concepts of chemical reactions, 2) chemical equilibrium, 3) Le Chatelier's principle, and 4) the factors that affect chemical equilibrium. After attending the PD activities, six classroom observations were carried out: 1) rate of chemical reaction, 2) an experiment about rate of chemical reaction, 3) discussion of the experiment about rate of chemical reaction, 4) factors that affected rate of chemical reaction, 5) factors that affected rate of chemical reaction (experiment), and 6) solving problems about rate of chemical reaction.

In practice, Ms. Ratree usually taught key concepts followed by some experiments related to the concepts. Ms. Ratree seemed friendly with her students. Most of the students also paid attention to the lesson. When students made noises that interrupted the teacher’s lecture, Ms. Ratree warned them and asked them to be quiet. She used a microphone to increase the volume of her voice which was very helpful for her to control the classroom. She could explain about the subject concepts fluently. She explained about the concepts while writing on the blackboard. In addition, she sometimes used an LCD projector to present concepts summary or how to solve Chemistry problems step-by-step.

Student Background

In academic year 2009, the researcher investigated Ms. Ratree's teaching Chemistry to a classroom of 12th grade students. The class took place in a chemistry laboratory. The class included a total of 36 students: 20 males and 16 females. In the previous academic year, most of the students in this class got Chemistry grade in the range of 2.00 -3.50. They were moderate in science subject learning. According to the interview with four volunteer students who got different grades in Chemistry (the grades including 1.00, 1.50, 3.50, and 4.00), they liked to study chemistry with Ms. Ratree. They said that they liked this subject because of having opportunities to do experiments. Their major aim of learning Chemistry was applying knowledge to real life. In the academic year 2009, the students did group work of 4-6 students for experiments; the groups were mixed genders and selected by themselves. According to observations, the students seemed not to be active as much as they should; they always came late to the classroom because of moving from another room. In addition, some students took Girl and Boy Scout courses before chemistry class. They had to perform activities for such courses outside the school. So, the teacher gave wait-time for them up to 15 minutes before starting the lesson in case of their coming late.

Classroom Setting

The classroom tables were organized into four rows. One table served for 2 groups of students: 4 to 6 persons in each group as shown in Figure 4.4. The wall was decorated with illustrations related to science and school activities. The table of the teacher was located in the front of the room. The room had a LCD projector set to support teaching presentations. The blackboard was located in the front of the room. The classroom also had three sets of computers with Internet. The school expected that these computers helped the students to search academic information. However, the students rarely used them. At the back of the room, there was a shelf with scientific models and baskets of basic experimental instruments for each group. A washing zone was located at the right hand side.

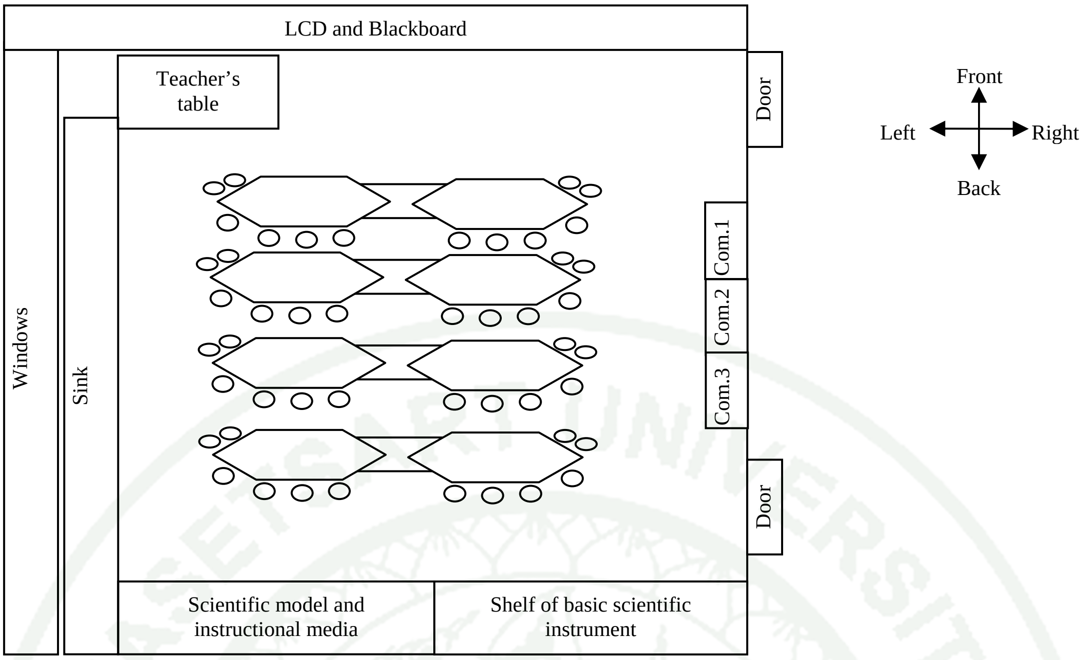

Figure 4.4 Layout of the Grade 12 Chemistry Laboratory

There was another room for chemical preparation and keeping scientific instruments. The students had to take some of chemicals and instruments from this room to the laboratory.

Findings about Ms. Ratree's Teaching for Critical Thinking

The following discussions involve the research findings related to teachers' understanding of and teaching practices for CT. The results were drawn from the questionnaire, interviews with the teacher, classroom observations, and documents used as teaching materials. The discussions focus on what teachers' prior understanding of and teaching practices are and how the teacher changed her teaching practices after attending the PD activities.

The Findings before the PD Activities

Understanding of Teaching for Critical Thinking

The analysis of Ms. Ratree's understanding of teaching for CT prior to the PD activities revealed that Ms. Ratree understood that teaching for CT focused on integration between studying subjects and applying knowledge. She defined in the initial interview that, "CT refers to thinking ability which is related not only to integration of subjects knowledge and creative thinking, but also positive thinking in order to benefit students and society" (The initial interview: August 4, 2009). She stated that CT was very important for academic learning and living in the real world. She also gave some characteristics of a student who was a critical thinker as a person who tended to practice what should be done in the actual world outside of class.

According to Ms. Ratree's statement in a post-class interview, teaching methods that were effective in promoting students' CT involved linking studied knowledge to their daily lives and integration of various concepts. She also suggested that, "In order to promote students' CT, teachers should allow students to share ideas, and set up suitable learning activities for them. Doing experiments and teaching content knowledge are appropriate to encourage students to think critically" (Interview: September 15, 2009).

Based upon the above statements, it could be said that Ms. Ratree held a rather superficial understanding about CT. She defined CT as ability to apply integrated knowledge to real life. She also indicated in the questionnaire that, "CT refers to creative thinking, and positive thinking which students should evolve into good thinking and good practices" (The questionnaire: August 18, 2009). This evidence suggested that Ratree held various meanings of CT. Theorists refer to CT as reasonable, reflective, and responsible thinking in order to make a decision or judge an argument (Bailin *et al*., 1999b; Chatkup and Chuchart, 2001). Conceptually, though creative thinking, positive thinking and critical thinking are considered as higher-order thinking, they are completely different from each other (Paul and Elder, 2007a). However, Ms. Ratree seemed to perceive that they were similar altogether.

Ms. Ratree held some beliefs that supported teaching for CT. Asking students' agreement about learning activities proposed by classroom members was a way to create good classroom environment that would increase students' interest in learning activities. As she said in the initial interview that,

> I think that activities that will support students in CT ability are activities that students and teachers agreed upon. For me, I will talk to them in the first lesson of each semester. I will introduce the concepts to be taught, assign their tasks, explain about the grading criteria, and ask them to present their ideas about the suggested activities.
>
> (The initial interview: August, 2009)

Ms. Ratree said in the interview if students were involved in planning how the class would be run, they would be encouraged to do their best in learning activities. Doing experiments is also a good way to develop students' CT based on Ms. Ratree's perception in the interview and the questionnaire. However, she stated that her major purpose of assigning students to do experiments was to teach them techniques for using scientific instruments such as droppers, cylinders, and volumetric flasks. She said that her students seemed to have difficulties in using such instruments correctly.

In addition, Ms. Ratree held a belief that might obstruct teaching for CT. She reported in the initial interview that teaching for CT involved focusing on covering all subject matters. She also said that students would think critically during studying a great amount of subject knowledge. They would apply such knowledge to their real lives. According to Zohar (2004) and Torff (2006), teachers who believed that they needed to cover all content knowledge usually conducted lessons by talking and describing what they wanted students to learn. Eventually, students would become passive learners who had limitation in developing their learning and thinking abilities. Therefore, this perception of Ms. Ratree's was possible to limit students' CT.

Although Ms. Ratree said that CT was very important for supporting students' learning, she reported that it was very difficult to provide students with learning activities that required CT. She said that it was enough if her students understood science concepts, so she was more concerned about covering all content knowledge than developing students' CT, which could be done later. She said,

> In reality, students often forget what they have learned, so they ask me to give them a review about basic knowledge needed for the class. For example, when we studied about pH, I had to explain to the class how to solve logarithm problems. So, it is very hard if the class has to be concerned with CT when students still lack of basic knowledge.
>
> (Interview: September 15, 2009).

In summary, Ms. Ratree seemed to be unfamiliar with the definition of CT prior to attending the PD activities. She was also poor to suggest teaching methods in the context of teaching for CT in Chemistry. She held some beliefs that seemed to hinder teaching for CT, such as: 1) her belief that teaching as much content knowledge as possible represents teaching for CT, 2) her belief that teaching for CT was difficult for teachers, and 3) her belief that CT was important for students' lives, but it was enough for her just to help students understand scientific concepts.

Teaching Practices for Critical Thinking

This section presents the teacher's practices in conducting a classroom that were divided into 6 categories, including goals of teaching and teaching preparation, classroom activities, strategies to engage students in learning activities, questioning techniques and treatments of students' responses, cognitive levels of the tasks given to students, and learning assessment. The following subsections describe the teacher's practices in each category while driving her classes and whether those practices are to promote CT or not (Hofstein *et al.*, 2005; Barak *et al.*, 2007; Malamitsa *et al.*, 2009).

Goals of Teaching and Teaching Preparation

Based on the initial interview and the questionnaire before the PD activities, Ms. Ratree stated that her main goal of teaching was to develop students' content knowledge and covering subject matters indicated in the school curriculum. She expected that her students could pass school examinations and national examinations, such as the General Aptitude Test (GAT) and the Professional Aptitude Test (PAT). She wanted her students to get higher scores in such examinations than students from other famous schools. In addition, she aimed to teach students to use scientific instruments properly. These findings were supported by her lesson plans. She wrote focusing on development of students' abilities to remember and understand concepts as a learning objective. Also, she wrote in her lesson plan of chemical equilibrium that students should be able to draw equations of K based on the provided chemical reactions. That ability was considered low cognitive knowledge based on the revised taxonomy of cognitive learning (Slack, 1997; Anderson and Krathwohl, 2001; Amer, 2006).

The information obtained from her interviews before the PD activities suggested that Ms. Ratree was not aware of teaching for CT even though some learning activities provided by her were suitable to challenge students to think as in doing scientific experiments. She reported in the interview as follows,

Researcher: What are your goals in developing students in Chemistry?

Ms. Ratree: Actually, this semester is not supposed to have electrochemistry, but I want to teach it to students. So, they will be studying about electrochemistry, chemical equilibrium, and acid and base in one semester.

Researcher: Um, three big and key concepts in Chemistry.

Ms. Ratree: It will be hard work for them. So, I have to think about how to teach them as much as possible. I also want them to use instruments properly. Currently, some students still use a dropper by taking it up-side-down, or sometimes, they use one stirring rod for different solutions without cleaning.

Researcher: Do you think about promoting students' CT?

Ms. Ratree: It is difficult to do that. Even for basic concepts I have to re-teach it to them before teaching the planed concepts. So, there is not enough time to promote their CT even if I want to.

(Interview: August 18, 2009)

The information from the initial interview revealed that Ms. Ratree spent time preparing the concepts to teach, lesson handouts, an experimental notebook, and the chemicals and instruments needed for conducting the planed experiments respectively. Before teaching each lesson, she did review textbooks two or three times. She sometimes searched for further knowledge on the internet. She said that those preparations increased her confidence in teaching, which was shown in classroom observations. Ms. Ratree did not seem to be concerned about preparing lessons for developing students' CT. She mentioned, "There are many concepts to teach for this semester but I do not have enough time to cover them. So, I really do not concern myself with activities for developing students' CT" (The initial interview: August, 2009). The analysis of the findings in this section suggested that Ms. Ratree focused on developing her students in subject knowledge and academic competition rather CT ability. She was willing to develop her own understanding in subject knowledge in order to teach students such knowledge. Therefore, learning activities for CT were overlooked.

Classroom Activities

According to the observations of Ms. Ratree's classroom before the PD activities, Ms. Ratree usually acted as the director of the classroom activities. She would describe quickly what she wanted her students to know. For example, in her lecture about the factors affected K_{eq}, the teacher started with teaching basic knowledge needed for the concepts being taught. She reminded the class about forward and backward reactions using $PbCl_{l2}$ + heat <--> $Pb^{2+}_{(aq)}$ + $2Cl^{-}_{(aq)}$. She then wrote K_{eq} of the chemical reactions and asked where the positions of each component of the reaction for K_{eq} were. Next, she explained about the effects of temperature, pressure, and concentration of solution on K_{eq}. Ms. Ratree explained the concepts along with showing the content and examples prepared in a slide show through an LCD projector. Ms. Ratree explained step-by-step about how to draw and calculate K_{eq} of the provided chemical reactions. Before the end of the lesson, Ms. Ratree talked about what students would study in the next lesson. She told the class that, in the next lesson, she would explain about experimental procedure for an experiment on the factors affecting K_{eq} (the class already learned this lesson). She planned to let students do the experiment in the lesson after next. This event suggested that Ms. Ratree taught or gave scientific knowledge and steps to determine experiments based on the textbook prior to letting them do scientific investigation.

To run an experiment on factors affecting K_{eq}, Ms. Ratree initially explained the experimental procedure and she demonstrated the steps of the experiment. She gave students theoretical findings that students were supposed to gain from observing the experiment on how chemical reactions changed. Most of the students paid attention to what she was talking about. After the teacher had finished briefing the experiment, students started to perform it. Some of them did the experiment while the others of them were writing items in the experimental report. They completed some questions by studying the textbook without using the results of the experiment. Finally, the whole class recorded the same data of the experiment because the class had only one set of the experimental data. Students had to hand in the completed experimental report the next day. There were no discussions about the experiment at the end of the lesson. These findings suggested Ms. Ratree did not conduct classrooms in a way that promoted students to think critically, although she thought that she had done her best for students. She said,

> I am satisfied with them. They have to do other activities such as Boy Scouts, which they have to study outside of the school before coming to the class. They looked tired (but still paid attention to the lesson), so it is reasonable to conduct the class the way it is. I am aware that in order to encourage students to think critically, it is not good to tell them about concepts before they do an

experiment. However, they generally do not read about experiment prior to class, so I have to explain it to them before letting them do an experiment.

(Interview: September 15, 2009)

According to the analysis of the teacher's teaching practices in this section, the results implied that Ms. Ratree was aware that she did not use the best classroom activities. She thought, at least, students had opportunities to run experiments. That was enough for her in this class. These practices and perception seemed to hinder her development in teaching for CT.

Strategies to Engage Students in Learning Activities

The results from the classroom observations before the PD activities showed that Ms. Ratree was not good in engaging students in learning activities. For example, she assigned the class to do some experiments on factors affecting K_{eq} of the chemical reactions by $Fe3^{+}_{(aq)}$ + $SCN^{-}_{(aq)}$ <-> $[FeSCN]^{2+}_{(aq)}$. She engaged students in the lesson while she was describing and demonstrating the experimental procedure by calling a volunteer student to help her in demonstration. However, some students who sat in the back of the class were not interested in her demonstration. They talked about other things with friends. Ms. Ratree appeared to ignore such students' behavior. The experiment was also conducted by a small group of 6-7 students, which would give the experimental data to the whole class. Another example was during a lecture, she sometimes called individual students to answer her questions. But, she would answer the questions herself because the students became quiet. The results in this section suggested that Ms. Ratree had limited techniques to engage students in classroom activities which might affect students' development in CT ability (Stillings and Wenk, 1999; Alazzi, 2008).

Questioning Techniques and Treatments of Students' Responses

The information from Ms. Ratree's first interview and the questionnaire showed that Ms. Ratree agreed that asking questions was a good way to encourage students to think critically. The result was also supported by the findings from her observed classroom practices. The findings about Ms. Ratree's teaching practices before the PD activities showed that she asked students questions. However, she did not raise questions in a way that encouraged students' CT. Most of the questions were yes-no and short-answer questions. Ms. Ratree mentioned in the interview that, "I question them (the students) to motivate them to think about the questions and the concepts I taught. I can also check whether they are listening to what I am teaching. If they can answer they will, but if some questions are too complicated, such as "How pressure affect direction of chemical reactions?" I have to explain to them again" (Interview: August 25, 2009). The findings suggested that Ms. Ratree raised such questions to motivate students' attention, but she provided too little time for students to think about the questions. She seemed to ignore whether students answered or not. Most of the questions were answered by the teacher even though she called on students to answer individually.

Regarding how Ms. Ratree treated students' responses based on our classroom observations, Ms. Ratree seemed to give little feedbacks to students' responses. According to the observed teaching practices before the PD activities, Ms. Ratree reacted to students' wrong answers by either saying "no" followed by giving the correct answer immediately, or ignoring such wrong responses and moving to ask another student with the same questions. She said in an interview that, "It is not serious if the students give wrong answers; the important thing is that I want to ask them questions in order to engage them in the lesson. In addition, the questions are very helpful to examine whether students understand what I am teaching or not. If not, I might re-teach them such key concepts" (Interview: August 25, 2009). Ms. Ratree also mentioned that she felt good to teach this class. She said,

> For this class, students are good enough. They have just moved from another room to study Chemistry, and then, they have to move to another one afterward. So, they look tired. Moreover, we have to think about the nature of the learners too. Some students are active in learning, but some are not. They are able to learn when they are ready. At least these students are polite. That is enough.
>
> (Interview: September 15, 2009)

The analysis of Ms. Ratree's teaching practice in this section suggested that Ms. Ratree used questions to gain students' attention in class rather than to challenge students to think critically to answer the questions. So, she did not use students' responses as clues to find a way to help them in learning and thinking.

Cognitive Levels of the Tasks Given to Students

The tasks, that Ms. Ratree prepared for students, included tests, worksheets, experimental reports, and activities during classes. The analysis of those tasks was done during the class observations. Before attending the PD activities, the researcher found that most of the tasks required students to think critically to complete the tasks, such as doing experiments, and reporting experimental data and conclusions. However, the tasks seemed to be used in a way that made students passive. During the experiment session, only a small number of students concentrated on doing the experiment. Almost all of the class members were not involved in the experimental procedure. They lost a good chance to participate in a learning activity that would promote their CT. Writing experimental reports also required students to use their CT. However, in practice, the teacher gave guided information or knowledge to write in the report before students started the experiment. In addition, the mid-term and final examinations only involved multiple-choice tests, with mixing levels of difficulties. Therefore, the analysis of the cognitive levels of the tasks that Ms. Ratree gave to her students suggested that the tasks should promote students' CT, but they were given in a way that might not motivate students' CT as much as they should.

Learning Assessment

The findings regarding how Ms. Ratree assessed students' learning were drawn from interviews and her teaching materials. The findings showed that Ms. Ratree intended to assess students' content knowledge corresponding to her goals of teaching. She used summative assessment utilizing a paper-and-pencil test as a major method to grade her students. She said that she did not think about ways to assess students' CT before. She said that she aimed to develop students' scientific skills by providing experiments for them, but she did not examine how the students developed themselves while they were doing scientific experiments.

In summary, the analysis of findings regarding Ms. Ratree's understanding of and teaching practices for CT prior to the PD activities provided by the PD program suggested that Ms. Ratree had little understanding about CT and teaching techniques for CT in Chemistry. She also did not intend to develop students' CT, but rather, she aimed to cover content knowledge indicated in the school curriculum as much as possible. With respect to teaching practices, Ms. Ratree appeared to conduct her lessons following transmission of knowledge and teacher-driven approaches. Therefore, the results before the PD activities suggested that Ms. Ratree had little understanding of and teaching practices for CT.

The Findings after the PD Activities

Understanding of Teaching for Critical Thinking

The analysis of Ms. Ratree's understanding of teaching for CT after the PD activities suggested that Ms. Ratree gradually increased her understanding of teaching for CT. At the workshop, Ms. Ratree shared her understanding of teaching for CT with the other participants. She defined CT as the ability to integrate knowledge that students already learned. She also defined the characteristics of a critical thinker as follows,

> A critical thinker should be able to apply knowledge to real life. As in making fireworks for traditional celebrations (Note: Thai people usually celebrate their local customs with fireworks), students develop their thinking abilities by trying to get better fireworks by varying the ingredients.
>
> (The first day of the workshop: October 27, 2009)

Ms. Ratree had a slight change of understanding of teaching for CT throughout the workshop. She defined CT as the ability to make a reflective decision and to complete tasks which required integration of knowledge. In addition, Ms. Ratree stated during an interview that, “I think that I conducted my lesson in a good way. I motivated students to think critically by involving them in classroom activities. I asked for a volunteer to draw an equation of rate of chemical reactions. But, I think they might be shy. So, instead, I asked a pair of them to write the equation” (Interview: January 5, 2010). This was evidence that Ms. Ratree had improved in her teaching practices to develop students’ participation, compared with the beginning of the study. The assertion was supported by the data from the interview, in which Ms. Ratree talked about questioning techniques for promoting students’ CT as follows,

> In the workshop, I have learned that questioning technique affected on the students’ thinking abilities. Teachers have to ask them questions and ask for their supporting reasons for the answers as well. For instance, yes-no questions and short-answer questions only hinder students’ thinking. So, we should provide open-ended questions, and add more questions to inquire what students are thinking based on the original questions.
>
> (The final interview: January 12, 2010)

Furthermore, Ms. Ratree reported in reflective journal based on classroom practices that good experiments that would promote students’ CT had to require students’ participation. Assigning every group to do an experiment enabled students to think more critically than assigning only a small number of students to conduct the experiment. She reported that, “In the previous semester, only some students were assigned to do experiments, and then, everyone in the class used the same data to write experimental reports. Actually, if they all participated in the experiments, they would have developed their scientific skills and thinking through solving problems and applying knowledge to complete the experiments. So, in the next lesson, I will direct them to do experiments in their own groups” (Reflective Journal: December 14, 2009). According to above findings, it appeared that Ms. Ratree had increasing understanding of teaching for CT during her participation in the PD program.

Teaching Practices for Critical Thinking

Goals of Teaching and Teaching Preparation

The analysis of the change in Ms. Ratree's goals of teaching and teaching preparation after the PD activities showed that Ms. Ratree changed to intend to develop students both in content knowledge and CT ability. The learning objectives in her lesson plans were changed to address students' CT development. For example, she wrote the learning objectives for the topic of the rate of chemical reactions as follows: 1) to identify how some factors affect the rate of chemical reactions, 2) to draw a graph showing the relation between concentration and time based on an experiment, and 3) to compare the rate of change of each substance in chemical reactions under controlled conditions. To accomplish those objectives, students had to use CT skills. Ratree also stated her intention to develop students' CT while preparing lessons. She said,

> I think more about learning activities. I want the students to participate actively in learning activities. Providing students with experiments to conduct and ask questions that motivate them to think about the experiments and also encourage them to think critically.
>
> (The final interview: January 12, 2010)

The findings from the interviews after the PD activities also suggested that Ms. Ratree prepared how to implement lessons in a way that would promote students' CT. Especially in experiment sessions; she set up the lessons differently from what she did before the PD activities. She planned that all students had to be involved in experimental procedure. They also had to draw conclusions based on experimental data together. She said that participating in the PD program motivated her to think more about providing learning activities in order to motivate students' CT. She said,

> I plan about how to encourage students via learning activities. For example, they have to write the theory and the experimental procedure before they come to

class. If I have enough time, I will let them discuss about the experiment with the whole class, and then, students are supposed to answer.

(The final interview: January 12, 2010)

Therefore, it appeared that Ms. Ratree became more aware of teaching for CT and she could also plan classroom activities in the context of teaching for CT, compared to what she did at the beginning of the study.

Classroom Activities

The findings from classroom observations following the PD activities suggested that Ms. Ratree's classroom practices were gradually shifting from transmission of knowledge to encouraging interaction and participation of students in learning activities that motivated CT. To conduct lessons, Ms. Ratree used students' questions to drive the class. For example, while she was talking about the rate of chemical reactions, she compared it to a situation related to students as follows:

Ms. Ratree: What's the, rate of chemical reactions?

Students: Changes of reactions.

Ms. Ratree: Um, changes of reactions. That's similar, but…not quite. Assume that you are driving a car from the school to Major Cineplex (a famous theater around there) at a constant speed, how long will it take you to arrive there if distance is 30 km?

Students: 15 min. (Some students answered 20 min., 30 min. with laughter).

Ms. Ratree: Why did some student answer 15, some answer 20, and some answer 30 minutes? Why?

Students: Driving slow or fast.

Ms. Ratree: Yes, slow or fast. Similar to the rate of chemical reactions, it means how fast the reactions take place.

Students: Teacher, what if there is traffic jam.

Ms. Ratree: Good question: What if there is a traffic jam? A traffic jam can be compared to a factor which obstructs chemical reactions. You will study about this later, and you will get to do an experiment on the factors affecting the rate of chemical reactions as well.

(Classroom observation: December 14, 2009)

She also said during the workshop after discussing with the other participants about how to select, assess, and organize plenty of information from the internet as follows:

> Providing students with opportunities to search for some topics is a good way to develop their CT. They have to think which resources are reliable, and then plan and organize information in order to engage the other students in class to pay more attention to their presentation.
>
> (The first day of the workshop: October 27, 2009)

In the actual the experiment session on the rate of chemical reactions, Ms. Ratree conducted the session in different ways from before she attended the PD activities, in which she drew and gave clear steps of the experiment to be conducted and the findings to students at the beginning of the session. However, the observed classroom activities after the PD activities showed that she assigned students to write experimental procedure before they came to class. The session started with Ms. Ratree briefing steps of the experiment. Based on the researcher's observation, Ms. Ratree appeared to be more concerned about students' responses to her questions than before the PD activities. The data from an interview suggested that Ms. Ratree also felt that she conducted the experiment with greater participation from students. She said,

> All of the students were responsible for conducting the experiment collaboratively. Each group had to use their own data to write an experimental report, so they all had to participate in the experiment. They learned to adjust the factors (temperature, concentration, surface, catalysts, and inhibitors) that

> affected the rate of chemical reactions. Finally, they were able to report the factors influence the chemical reactions.
>
> (Interview: January 12, 2010)

At the end of the experiment session, Ms. Ratree led students to discuss about the observed changes and chemical reactions based on the experiments. Then, the class summarized key concepts and drew conclusions on the experiments. She talked to students after they got results of the experiments as follows:

> Okay, every group has got the results already, right? So, each group may compare your results with the others. I'll let you think about what the differences or the similarities mean. However, you have to conclude the experiments based on your group's results.
>
> (Classroom observation: January 12, 2010)

These findings suggested that Ms. Ratree had included more classroom practices for CT during the PD program.

Strategies to Engage Students in Learning Activities

The analysis of Ms. Ratree's strategies to engage students in classroom activities after the PD activities was drawn from classroom observations, interviews and reflective journal. The results showed that Ms. Ratree gradually improved in engaging students in learning activities after the PD activities. She employed various techniques in order to engage students in learning activities. For example, she let them discuss the experimental data on the effects of substance concentrations (Sodiumthiosulphate: $Na_2S_2O_3$, and Hydrochoric acid: HCl) on the rate of chemical reactions. A volunteer group presented their data on the blackboard and Ms. Ratree led the class to calculate the concentrations of each solution based on the data. Then, two students in the volunteer group drew equations of the rate of chemical reactions for each data. Then, everyone in class discussed about the relation between the solution concentration and the rate of chemical reactions. Finally, the class concluded that the rate of the chemical reactions decreased when the concentration decreased. Then, each group wrote their own experimental report to submit to the teacher on the next day. In addition, she engaged students in lessons by other techniques, such as asking for volunteers to solve problems about the rate of chemical reactions, giving special marks to students who were able to solve difficult problems, and using collaborative learning in conducting experiments in small groups. Ms. Ratree reflected on what she had learned from her participation in the PD program that,

> Actually, I have never thought about how to engage students in active participation. I just attempted to cover a huge amount of content knowledge by telling them what they must know. However, participating in the PD program encourages me to re-consider my own teaching practices. Now, I concentrate more on planning and implementing learning activities to promote students' interaction and answering questions.
>
> (Reflective journal: February 7, 2010)

According to these findings, it can be said that Ms. Ratree had improved in using techniques to engage students in learning activities, compared to before. The students were more involved in hands-on and mind-on activities and expressed their thoughts more critically.

Questioning Techniques and Treatments of Students' Responses

The results of this section were based on classroom observations. The findings suggested that Ms. Ratree had some improvement in using questions and words to promote the students' CT. The researcher felt that Ms. Ratree used better questions and provided longer time to wait for students' answers. Sometimes, she answered the questions by herself when there was no response from the class. She also used questions to encourage students to predict what was going to happen while she was demonstrating how to do some steps of an experiment by asking questions, such as "What would happen if we added more $Na_2S_2O_3$ into HCl?" and "What factors do you think affect the rate of chemical reactions?" (Classroom observation: January 7, 2010). Ms. Ratree used words to encourage students' thinking during lessons. She said while she was introducing students to the experiment, "Give me examples of something that is slowly or rapidly changing in our daily lives" (Classroom observation: December 22, 2009).

The findings based on classroom observations after the PD activities showed that Ms. Ratree had a bit of a change in giving feedbacks to students' responses. She was better in creating a classroom of active participation by directing students to do experiments within their groups. However, some students did not care to help their groups. Ms. Ratree appeared to ignore such situation. She said "no" for wrong responses and gave a bit more time to let the same student think about the answer again. She sometimes moved to other students, and asked "Do you agree or not agree with the answer?" She also asked for further reasons from the students. She re-asked the same question a few times, and then, she gave the correct answer when there was no more answer from the students. This evidence could imply that Ms. Ratree was better in using questions to encourage students to think, compared to the beginning of the study.

Cognitive Levels of the Tasks Given to Students

The analysis of the cognitive levels of the tasks that Ms. Ratree provided for students after the PD activities was drawn from classroom observations and her teaching materials. The results suggested that she was better in assigning tasks to promote students' CT. Especially, she emphasized students to complete the written tests, in which she presented some complicated items for the whole class later. Moreover, students had to participate in doing experiments more than they used to do in the first semester. They had to draw diagrams showing experimental procedures before they came to class. They were involved in discussion and drawing the conclusion of the experiments. Ms. Ratree also called for volunteers to solve a complicated chemical reactions problem in front of the class. The volunteers helped each other to complete the problem while the other students also suggested the next steps or guided the volunteers to make a decision in further steps. These were evidences that Ms. Ratree had got better at providing better cognitive tasks for the students throughout the PD program.

Learning Assessment

The results of learning assessment section after the PD activities implied that Ms. Ratree made gradual improvement in assessment practices. She included both outcome and process assessments in her classes, corresponding to teaching for CT. She used a variety of tests involving basic and more complicated items. Students had to use their thinking abilities by drawing a conclusion based on the given information. That assessment also examined what students had learned in the lessons. Ms. Ratree also observed students' scientific skills and scientific process while students were conducting experiments. Ms. Ratree said that she assessed students' CT during teaching as well. Although she did not give scores for every question answered, it was very useful for her to know whether the students learned. She felt that the classroom was alive when students interacted with each other and actively participated in the learning process. They looked enthusiastic in helping their peers to solve difficult Chemistry problems. It was fair to conclude that Ms. Ratree had improved in assessing students' CT to some extent.

Factors that Influence Ms. Ratree's Teaching for Critical Thinking

Working with Ms. Ratree for an entire academic year allows the researcher to discover the factors that influenced Ms. Ratree's teaching practices for CT. Those factors included the teacher, students, time, and additional school activities.

Ms. Ratree looked confident in the subject she taught. Therefore, she mostly focused on providing as much knowledge as possible for national examinations, rather than teaching for CT. She realized the importance of CT in promoting students' learning and living in the real world. She also mentioned that she conducted classroom activities similar to what she were engaged in when she was a student. So, she believed that traditional teaching and learning approaches were proper to support students' learning in the present. She also had less experience in teaching (3 years). She might learn how to teach for CT from experiencing a variety of classroom situations. In addition, she often said that she was satisfied with the class as it was. However, throughout the PD program, she gradually realized that she would like to improve her teaching for CT.

The students' background also affected teaching for critical thinking. Her students lacked intrinsic motivation to learn. They were apathetic and passive learners and they generally came to class late. They were not enthusiastic about engaging in cognitive tasks, such as doing experiments. They also paid little attention in classroom activities.

Time and additional school activities were related to each other. Classes lost some learning time because of other school activities. This made the teacher decide to ignore learning activities that required students' CT. She stated that if she employed learning activities for developing students' CT, she could not cover a large amount of content knowledge.

The Teachers' Learning as a Result of Participation in the PD Program

The researcher evaluated the effects of the PD program on Ratree's understanding of and teaching practices for CT in chemistry. The comparison of teaching for CT between before and after the PD activities is displayed in Table 4.3

Table 4.3 Comparison of Ratree's Understanding of and Teaching Practices for CT before and after the PD Activities

	Components	**Findings**	
		Before the PD activities	**After the PD activities**
Understanding	Meaning of CT	Ability to integrate knowledge among subjects, creative thinking, and positive thinking	Ability to make decisions, and complete tasks by integration of knowledge among subjects

Table 4.3 (Continued)

	Components	Findings	
		Before the PD activities	**After the PD activities**
Understanding	Awareness of teaching for CT	Benefits for students' studying and lives	Benefits for students' studying and lives
	Identifying teaching for CT	Linking knowledge to daily life and subject integration, doing experiments, covering content knowledge	Asking questions with supporting reasons, doing experiments with students' active participation
Teaching practices	Goals of teaching	Developing students in content knowledge, and using scientific instruments	Developing students in content knowledge, scientific skills, and experiment, CT
	Teaching preparation	Preparing contents, teaching documents, and experiments	Preparing content, teaching documents, experiments, and ways to conduct lessons to develop students' CT
	Classroom activities	Teachers' talking about teaching concepts, describing experiment procedures, and telling what results should be gotten from the experiment	Teachers' talking about concepts and experiments procedures, and leading the students to discuss and conclude the experiment
	Strategies to Engage Students in Learning Activities	Asking questions by calling on individuals and volunteers to answer	Asking volunteers to solve chemistry problems, giving special scores, and using group activities
	Questioning techniques and treatments of students' responses	Using yes-no and memorizing questions, the questions answered by the teacher, giving few feedbacks to students' responses or moving to other students	Providing wait-time, calling individuals or groups to answer, treating to students' responses by asking other students and adding basic questions before returning to the original questions

Table 4.3 (Continued)

	Components	Findings	
		Before the PD activities	**After the PD activities**
Teaching Practices	Cognitive levels of the tasks given to students	Tests, exercises, experiment reports (students do them with no discussion in the class)	Tests, exercises, experiment reports (increasing students' active participantation)
	Learning assessment	Assessing students' knowledge in content using paper-pencil test	Using paper-pencil test, and authentic assessments examine student knowledge and skills

In conclusion, the findings implied that the PD program was able to enhance Ms. Ratree's teaching practices in the context of teaching for CT. At the beginning of the study, she defined CT as an ability to integrate knowledge from various subjects, creative thinking and positive thinking. So, teaching for CT should involve knowledge integration, doing experiments, and covering content knowledge. Her understanding largely affected her teaching practices. She did not aim to develop students' thinking abilities. She believed that teaching for CT was important to students' learning and living in the real world, but it was very difficult in practice to implement. On the other hand, the students needed to master a huge amount of subject matters. They needed to cover it all for succeeding on national examinations.

After attending the PD activities, she defined CT closer to its theoretical meaning. She mentioned that CT referred to an ability to make decisions and solve cognitive problems. Characteristics of teaching for CT focused on students' interaction and participation. She conducted better classes, which encouraged students in learning activities more than before. Students answered her questions, participated actively in experiments, and solved chemical reaction problems. She also reflected that participating in the PD program encouraged her to consider and plan learning activities. She just realized that it was possible to integrate teaching for CT with Chemistry teaching. In the end, the results of the study showed Ms. Ratree's improvement in teaching for CT, compared to the beginning of the study.

Summary

According to the results from a within-case analysis of individual participant teachers related to their understanding of and teaching practices for CT, the findings revealed that they realized the importance of CT at the fast and competitive society nowadays. However, at the beginning of the study, two of them, Mr. Artid and Ms. Ratree seemed not to be aware of integrating teaching for CT into their classrooms. Though, Ms. Tawan said that she would like to teach for developing students' CT, but in practice, she conducted teaching in a small extent corresponding to teaching for CT.

The observed findings from the participant teachers after they attended the PD activities on teaching for CT showed that all of them had improvement in teaching for CT. They had a greater understanding of teaching for CT as well as they illustrated an increasing number of pedagogical developments of teaching for CT. Teaching techniques such as asking questions, strategies to engage students in learning activities, and cognitive levels of the tasks given to the students were implemented in order challenge the students to think critically. There are some factors seeming to affect on the participant teachers' teaching for CT such as teacher background, teaching experience, their students' background, and the school content. The findings from a within-case analysis that were illustrated already in this chapter are crucial information for a cross-case analysis would be presented in Chapter V. The results from both a within-case and a cross-case analysis became essential for determining effectiveness of the professional learning activities provided in the PD program.

CHAPTER V

COMMON FINDINGS FROM A CROSS-CASE ANALYSIS OF PARTICIPANT TEACHERS

Introduction

The purpose of this chapter is to illustrate common findings from three participant teachers. The analysis is on teachers' understanding of and teaching practices for CT. The findings of individual teachers from the within-case study in Chapter IV are illustrated both similarities and differences altogether through this chapter. By comparing and contrasting cases, it can be better ascertained how the teachers changed their teaching practices in the context of teaching for CT after participating in the PD activities. Factors that supported or obstructed the teachers' development in teaching practices for CT also are revealed. The results from the cross-case analysis also help to respond to research questions: 1) what is chemistry teachers' prior understanding of and teaching practices for CT? and 2) how does the PD program affect on teachers' teaching for CT? The last section of this chapter presents the discussion about those common findings.

The Participant Teachers' Prior Teaching for Critical Thinking

The results of the cross-case analysis presented in this section regard to the gained findings before participant teachers attending the PD activities. The analysis also is taken into account the participant teachers' background information, such as education, teaching experience, professional training experience, and their students.

The Participants Had Little Familiarity with the Definition of CT

Theoretically, there is no exact definition of critical thinking; it has been debatable for long time. However, most of the well-known concepts given by key theorists like Ennis (1987), Paul (1990), and Lipman (1991) present similar features of

CT as purposeful, reflective and rational thought in order to solve problems, interpret information, draw conclusions, evaluate arguments, and make decisions (Bailin *et al*., 1999b; IPST, 2001; Facione *et al*., 2000). Working with participant teachers, it appeared that they held only a small portion of the conceptual meaning of CT. Especially, Mr. Artid and Ms. Ratree, according to the questionnaire and the initial interview with them had little familiarity with the full definition of CT. As the initial interview, Mr. Artid indicated that, "Um, critical thinking, it is the meaning itself. It might refer to giving reasons. The students should be able to point out their supporting reasons for answers." (The initial interview: August 3, 2009). Differently, Ms. Ratree defined CT as ability to integrate knowledge among various subjects and link knowledge to daily life (The initial interview: August 4, 2009). Out of three participants, Ms. Tawan seemed to hold the definition of CT closest to the theoretical concepts. According to the initial interview with Tawan, she referred CT as ability to reflective and analytic thinking and a set of higher-ordered thinking. The findings suggest that two out of three teachers had what might be considered a poor understanding of CT while another teacher had understanding of CT to some extent.

The Participants Recognized the Importance of CT in Students' Learning and Living in the Real World, but Seemed not to Intend to Integrate CT into Practices.

According to interviews prior to the PD activities, all three of teachers appeared to recognize the importance of CT for students' learning inside and outside schools. Ms. Tawan stated that CT was one of her goals of teaching; particularly for the special science student. However, the findings from her classroom observations appeared developing students' scientific knowledge. Mr. Artid and Ms. Ratree seemed not integrating teaching for CT into their classroom practices. Their classroom practices also supported their content-based teaching rather than teaching for CT. For example, Mr. Artid used a guided experimental data in the textbook for explaining relation of experimental variables (V_{gas} and P_{gas}) those two variables related each other. The class became less engaging students in discussion based upon their data.

The data from post-class interviews and the pre-workshop questionnaire reported that the participant teachers admitted the reasons that led them to avoid using CT activities in their classrooms were such as limitation of time and the students' backgrounds (by all three teachers) and lack of knowledge about teaching practices for CT (Mr. Artid). This finding bears similarity with the investigations of Zohar *et al*. (2001) and Torff and Sessons (2006). They found that most teachers recognized the increasing potential values of CT in world-wide and CT as a major goal of teaching across curriculum. However, those teachers still employed teaching practices based on transmission of knowledge. They also raised the reasons why they did not implement CT activities such as time constraints, different students' abilities, and teachers' lack of knowledge about teaching for CT.

The Participants Perceived "Critical Thinking" Activities as a Waste of Time and Something Separated from Chemistry Learning Activities; Thus, Transmission of Knowledge Approach Was Preferred.

Reported during their interviews before the PD activities, learning activities for developing students' CT took too much time whereas they needed to cover a huge amount of chemistry concepts in the school curriculum. Mr. Artid and Ms. Ratree said that they had no time to create CT tasks which took time both in preparation and implementation. They hence would not intentionally prepare CT activities for their students but would rather focus on transmitting chemistry knowledge to the students. Mr. Artid and Ms. Ratree appeared the perception of separation between content knowledge and CT activities. Something differently, regarding to post-class interview before the PD activities, Ms. Tawan said that her some chemistry tasks could support students' CT (e.g., asking them to demonstrate an experiment) while some learning activities seemed not promote students' CT (e.g., lecture quickly and just giving them steps of calculation). This evidence implied that two out of three teachers perceived that CT learning activities were isolated from chemistry subject learning activities offered for their students whereas only one teacher realized that teaching for CT could be embedded in chemistry learning activities. Similar finding was reported by Zohar (2004) and Torff (2006). They found that teachers understood that CT activities and school standard subject learning activities were separated; so the teachers decided to complete subject matter prior to incorporation of CT activities.

Based upon interviews before the PD activities, while the participant teachers suggested that teaching Chemistry to promote students' CT involved asking questions and doing experiment, they held idea that CT activities were independent from subject learning activities. This research finding suggested the teachers might be difficult to characterize CT activities. Theorists and educational scientists acknowledged an infusion approach of teaching CT which the approach suggested to teach CT by integrating into standard school subjects (Moore, 2004; Davies, 2006). Therefore, CT should not be separated from content knowledge tasks (Bailin *et al*., 1999b; UMUC, 2006; Willingham, 2007). For instance, students might learn chemistry concepts through discussion about graphical representations and numerical exercises with their peers (Wilson, 1999); they also should acquire scientific knowledge through inquired-based laboratories (Hofstein *et al*., 2004; Khan, 2007). More importantly, CT tasks require application of basic knowledge in particular fields through a variety of cognitive skills to complete (van Gelder, 2004; UMUC, 2006). Therefore, similar tasks will be solved in appropriate ways by a good critical thinker who possesses "know-how" while the same tasks may be difficult or completed in wrong ways by a poor critical thinker (Bailin *et al*., 1999a). However, a poor critical thinker is able to become a good critical thinker through practices and engagements in CT tasks and CT activities (van Gelder, 2004; UMUC, 2006; Willingham, 2007).

The Participants Perceived that CT Tasks Were for High Academic Achievers; Not Appropriated to Low Academic Achievers.

The results from interviews before the PD activities showed that all participant teachers held the idea of learning activities requiring CT for different student groups. All participants addressed that the students enrolling in special science classrooms (Emphasizing Physics, Biology, and Chemistry) represented the group of high academic achievers; they would enable to deal with CT tasks better than another group of ordinary science students. As Ms. Ratree talked about her students while doing an in-class experiment that,

> I had to draw experimental procedures on the blackboard even if the students would not do anything. My students are quite different from the other three classrooms in the school, in which those students are enrolled in the special science-and-mathematics program. Those students are more active, so they can deal with difficult tasks. For my students, if they at least sit in the classroom or just listen to me, that is already acceptable.
>
> (Interview: September 5, 2009)

Ms. Tawan and Mr. Artid also mentioned to using CT tasks with different groups of the students. These two teachers had taught at the same school with different groups of students. Mr. Artid taught ordinary science classrooms, while Ms. Tawan taught special science classrooms. Based upon Mr. Artid's post-class interviews of relation of gas variables, Mr. Artid pointed out some different characteristics of those students. He mentioned that his students were very quiet and had difficulties in doing experiments. So, doing exercises based on the textbooks was enough for them. Similarly, Ms. Tawan experiencing in teaching both ordinary and special science classrooms stated that, even with the same teaching contents between these two groups, she planned different classroom activities and tasks for them. Ms. Tawan said that, special science program students were able to do difficult assignments such as searching topics followed by doing presentation, while another group had difficulties in doing such tasks. So, she decided to just lecture the latter group. According to Ms. Tawan, ordinary science students had poor learning abilities -- they were slow in learning concepts. Some previous studies also reported that a key factor that led teachers not to use CT tasks was teachers' perception that CT tasks would make difficulty for low-achieving students (Zohar *et al*., 2001; Torff and Warburton, 2007; Barak *et al*., 2007). Therefore, it seems that teachers' perception of learning abilities among different groups of students has led them to avoid CT tasks for low academic achievers. If continued, the gap of thinking abilities between the two groups of students might grow continuously.

The Participants Perceived Teaching for CT Involving a Variety of Classroom Activities, in Practice, They Use Little Classroom Activities.

Promoting students' CT in learning Chemistry, the participant teachers agreed that a variety of classroom activities should be employed. According to the initial interviews and the pre-workshop questionnaire, teaching for CT, for example, included: asking questions and doing experiment (by all teachers), integrating knowledge subjects and real lives (by Ms. Ratree), and doing exercises in the textbooks as much as possible (by Mr. Artid). However, the teachers appeared superficial how to employ such activities for promoting CT. For example, they stated using questions as a good way to promote students' CT, but they did not characterize kinds of the questions. Only Mr. Artid pointed to the questions requiring students' reasons to support their answers. But, in practice, Mr. Artid appeared to use a small number of such questions and use close-ended questions. Ms. Tawan said that students would develop scientific skills while they did experiments. Students would think critically how to complete the experiment through planning with their group members. They would decide on replacing materials in case of lack of materials indicated in the experiment guide. These research findings suggested that all three teachers had a small understanding about teaching and learning activities for CT.

The Focuses of Teaching Are for Content Knowledge and National Examination throughout Teachers' Talk and Lecture.

The findings from classroom observations and interviews before the PD activities showed that the participant teachers conducted classrooms for coverage of subject matter indicated in the textbooks. During lessons, Mr. Artid would take the chemistry textbook into the class and looked at teaching concepts in the textbook many times in order to describe such concepts for his students. This event was supported by his initial interview and the pre-workshop questionnaire; he stated that he planned to teach for students' understanding as much as content knowledge and solving the calculating chemistry problems. While, Ms. Ratree stated in her initial interview that she had to teach for covering all key chemistry unites: chemical equilibrium, acid and base solutions, and rate of chemical reaction within one semester. Her actual practices before the PD activities also illustrated teachers' talk and lecture as a major practice. At the same time, almost all of her students just sat and had little interaction with teachers' teaching. As Bailin (2002) said, giving students content knowledge through traditional didactic lectures would make the students as passive learners. They might listen to a lecture and remember the knowledge in the short term, but the students would not develop abilities to think critically (Paul, 2005; Buntod *et al*., 2010).

According to classroom observations, all teachers assigned tasks for their students, but the tasks seemed to be directed by the teachers such as solving chemical problems and drawing conclusions of teaching concepts. The teachers stated that if they let their students handle such tasks independently; their students might gain misunderstanding about the concepts. It appears that the teachers judged their success in teaching based on the amount of content knowledge that they gave to the students.

In addition, all three teachers aimed to teach their students for overcoming school-based and national examinations. For example, Ms. Tawan, who often forced her students to pay attention on content knowledge for Olympic Examination, decided to skip the designed CT activities and used a traditional lecture method whenever she had limited time, especially in the final period of the semester. Similar to research findings of Torff and Sessions (2006), they found that most of 20 social study teachers stated that "time constraint" was a key issue that led them to keep away from CT activities which always took time. It could be said that before the participant teachers experienced the PD activities they performed lessons in ways of content-directed classrooms for covering required concepts in the school curriculum.

Little Encouraging Students' Discussions and Participations in Learning Activities

Simpson and Courtney (2008) suggested instructional strategies promoting CT dependant on level of students' discussions and participations in learning activities. Based upon classroom observations and interviews before the PD activities, it appeared that the participant teachers paid little attention to motivate their students' discussions and participations in lessons (Zohar and Nemet, 2002). They seemed to ignore determining whether their students followed what they were teaching. For example, during observations, Mr. Artid's students showed a small number of answers and responses to his teaching. Strategies increasing the students' participations also were not observed. In the laboratory lesson, Mr. Artid's classroom showed more students' participations comparing to his lecture. Some of his students performed experiments, but they just did experiments following a "cookbook" with little discussion based on the experiments. Similarly, Ms. Ratree ignored some students' talk loudly something without being taught and avoiding experiments with their peers. Something differently, Ms. Tawan's classrooms appeared more students' participation than the other cases. She engaged her students in activities by calling volunteers to demonstrating titration techniques. Perkins and Murphy (2006) and Alazzi (2008) argued that most of CT activities would motivate students to think critically better depending on levels of participating in activities. Thus, the research findings from the cross-case analysis in this section showed that the participant teachers illustrated few times to engage students' participation in classroom activities.

Using Yes-No and Memorizing Questions and Answering the Questions by the Teachers

An effective question is a great driving force for one's expressing thought (Slack, 1997; Stillings and Wenk, 1999; Wilson, 1999; Hofstein *et al.*, 2004; Tongpan *et al*., 2009). The ability to raise effective questions promoting students' CT of the participant teachers was investigated. In classroom practice all teachers raised yes-no and memorizing questions, and sometimes answered the questions themselves. Mr. Artid appeared to use close-ended questions requiring short answers. He seemed to ignore providing wait-time for students' answers and their reasons.

In order to motivate students to answer, repeating questions, calling other students to answers techniques were employed by all three teachers. Observations also suggested that all of them did not use questioning techniques that challenged students to think critically. Their questions might support and assess students' short-term memorization, but the students might not develop their CT. Ms. Tawan and Mr. Artid mentioned that they questioned the class to gain students' attention and ensure that they were listening to what they taught. At the end, the teachers answered the questions themselves. In addition, they had a few feedbacks to students' responses such saying "Right/good" or "Wrong". Regarding the use of questioning to promote students' CT, Slack (1997), Hofstein *et al*., (2004), and Perkins, and Murphy, (2006) characterized questions which supported or did not support students to think critically. The questions motivating students to think critically by expressing ideas and thoughts should be opened-ended questions in which required students to present reliable reasons and evidences. The participant teachers seemed to having less knowing-how to challenge students to think. Afterwards, the teachers needed to diagnose how to develop the students' CT (Zohar and Schwartzer, 2005). According to the cross-case analysis, the participant teachers seem to use little kinds of questions and questioning techniques to challenge students to think critically.

Conducting Laboratory with Little of Students' Active Participation in Inquiry-Based Investigations

Inquiry-based investigation is seen as an important teaching and learning science. By implementing inquiry-based investigations, students will develop themselves not only in scientific knowledge and scientific skills but also in problem solving and thinking abilities (Sanunoue, 1999; Zohar and Dori, 2003; Khan, 2007; Buntod *et al*., 2010). In order to cultivate CT through science lessons, the students should be deeply engaged in scientific inquiry-based learning (Balin, 2002; Hofstein *et al*., 2005; Malamitsa *et al*., 2009). Teaching method based on the 5E inquiry learning cycle, according to the studies of Pitagsalee *et al*. (2007), Tongpan *et al*. (2009), and Buntod *et al*. (2010), enabled students to developing in scientific understanding and CT abilities. The analysis of this study revealed a crucial problem that obstructed the development of the teachers' teaching practices for CT. The participant teachers seemed to lack knowledge and awareness of utilizing scientific laboratory lessons in ways contributing students' learning and CT.

In practice, Ms. Ratree conducted laboratory lessons nearly lectures. However, the experiments were not done by every student. There was only a small group of 5-7 students who were engaged in doing experiment. Similarly, Mr. Artid assigned his students to conduct an experiment which he just decided upon a few minutes before the laboratory lesson began such he said, "Okay, I did not plan to do experiment for this period. But, after I read about steps of the experiment, testing about V (volume) and P (pressure) of gas, it is not complicated and used available materials. So for now, you read the steps in the textbook, I will prepare some ice and chemicals. Read it about 5 minutes" (Classroom observations: September 16, 2009). This statement suggested that the students had very little time to read the experimental procedure. Some groups conducted the experiment incorrectly and skipped steps. The observed class showed that Mr. Artid did not suggest the students how to be active group members to the students who did not lend their hands in the experiment. The class also did not have collaborative discussions in order to draw conclusions for the experiment. For Ms. Tawan, her students participated in running experiments. They drew diagrams of the experimental procedure before they came into the laboratory. Each group member collaborated while running the experiment. However, the students still had little discussions in order to draw conclusions for the experiment. The finding of the cross-case analysis here suggested that the participant teachers set scientific experiments for their students, but the experiments were conducted with little scientific inquiries by the students. The students engaged just small analytic and reflective discussions based on the experiment. This experimental practice might block the students to develop their thinking critically.

Focusing on Content Knowledge Assessment Practices Using Paper-and-Pencil-Based Examinations

Regarding the participant teachers' assessment practices, the findings of the cross-case analysis were that they focused on the uses of summative assessment. They mostly employed paper-and-pencil tests in order to examine students' understanding. Most of tests were multiple-choice tests. Mr. Artid and Ms. Ratree stated clearly in their interviews before the PD activities that they did not think about how to assess students'

CT during their Chemistry lessons. They only wanted to know what content knowledge their students gained after learning the concepts.

Although the participant teachers wanted to develop students' scientific skills, classroom practices by Mr. Artid and Ms. Ratree showed that they ignored to examine what students were doing during a laboratory lesson; they let the students do experiment and in the end the students wrote an experimental report sending the teachers. Ms. Tawan said that she observed students' scientific skills while they were conducting experiments. She gave some feedback when students did something in the wrong ways or misused laboratory instruments. She would then follow whether such mistakes were improved in the next lesson. According to these findings, the participant teachers were not familiar with assessment practices in the context of teaching for CT. Stillings and Wenk (1999) suggested that assessing students' CT via active science classrooms was a fully beneficial method. They also addressed the usefulness of a paper-and-pencil test for generating open-ended and short-answer questions in order to assess students' reasoning abilities and challenge students to generate effective questions, arguments or draw conclusions based on the given situations. Most of the previous studies addressed helpful to assess students' CT via inquiry-based learning where the students embedded in scientific inquiry and solving problems with reasoning and purposeful thought (Pitagsalee *et al*., 2007; Khan, 2007; Buntod *et al*., 2010; Ketsing, 2010). Bailin (2002) and Zohar and Dori (2003), for instance, suggested that what could be assessed for CT involving designing an experiment, drawing conclusions based on evidences and data of experiments, or generating plausible alternative explanation of an observation. In conclusion, the participant teachers expressed less awareness of assessment practices, which utilize authentic assessments along with formative and summative assessment which are valuable to determine students' learning and thinking critically.

Playing the Role of a Key Source of Content Knowledge

The teacher is a critical factor in the current education system (Veal, 2004; Torff, 2006; Roehrig and Garrow, 2007; Yutakom and Chaiso, 2007). Challenging teachers to change their roles from a major source of content knowledge, based on traditional didactic lecture approach, to agents that help foster students' learning and thinking abilities based on a student-centered or constructive teaching approach is a crucial notion of educational development (Wilson, 1999; Watson, 2003; Moore, 2004; Willingham, 2005; Barak *et al*., 2007; Roehrig and Garrow, 2007; Alazzi, 2008). Teachers' roles accordance with such alternative teaching approaches are to create classroom environment which supports students' learning and thinking, and are to diagnose students' difficulties in learning and thinking in order to help the students effectively. However, the participant teachers in the current study played their roles as the providers of knowledge who transferred concepts from the curriculum into students' memory. They overlooked constructing active classrooms where students played the roles of active learners similar to the study of Stillings and Wenk (1999). Mr. Artid and Ms. Ratree demonstrated their roles by giving the students knowledge as much as they could. The participant teachers were also encouraged responsible of preparing CT tasks, such as worksheets and experimentations, but they were poor in implementing such tasks for promoting students' CT. It appeared that the participant teachers would give subject matter aiming the students to learn. The teachers seemed not practice in ways of challenging students to express reflective and reasoning thought.

The Changes of the Participant Teachers' Teaching for CT as the Results of Participating in the PD Program

Working with the participant teachers throughout an entire academic year 2009, the changes of pedagogical development of teaching for CT as the result of participating in the PD activities were apparent. Similar to studies of Krull *et al*. (2007), Nielsen *et al*. (2008), Van Es and Sherin (2008), and Roth *et al*. (2011), findings of these studies suggest that after teachers experience in effective professional learning activities and exchange their teaching profession with each other, they increase in their teaching profession.

The Development in Understanding of Teaching for Critical Thinking

At the beginning of the study, the participant teachers mentioned about the importance of CT. However, according to interviews and classroom observations before the PD activities they appeared to be aware of integrating teaching for CT in small extent. After their attending the PD activities, the findings from interviews suggested that the participant teachers shifted their understanding about CT; all of the participants defined CT as ability to reasoning and reflective thinking, solving problem in Chemistry, and making a decision. Additionally, Ms. Tawan and Ms. Ratree defined CT as ability to design and conduct an experiment, and to draw conclusions based on data and evidences in hands. Ms. Tawan still understood CT as one in a set of higher-ordered thinking like she perceived at the beginning of the study while Ms. Ratree pointed CT as ability to apply subject knowledge to real-life.

The participant teachers also identified more teaching strategies for promoting students' CT comparing to what they did prior to the PD activities. According to interviews and classroom observations prior to the PD activities, the teachers pointed ways to promote students' CT in Chemistry by asking questions and doing experiments. Following the PD activities, the data from interviews and classroom observations showed that the participants added more teaching strategies such like: using questioning techniques to challenge students to think critically, seeking particular research topics and doing presentation, working groups, doing experiments with active participation, and solving chemistry problems. These teaching strategies seem to contribute to the development of students' CT (Slack, 1997; Watts *et al*., 1997; Wolcott, 2000; Zohar and Weinberger 2000; Perkins and Murphy, 2006; Matchett, 2009).

The participant teachers also appeared increasing awareness of teaching for CT in their teaching after the PD activities. Ms. Tawan addressed during group meeting that, "…Teachers should intend to teach for CT. We are able to develop students' CT in teaching Chemistry even though lecturing lessons by using questions, providing group discussions to motivate students to think, and then they will select a decision together…" (The first group meeting: November 9, 2009). Ms. Ratree also stated that students should be involved in activities that developed their CT in order to help them to apply knowledge into real-life. Mr. Artid said that he would increase his students' interactions in classroom activities by using questioning techniques such as calling individuals or groups to answer to questions; he said that these strategies supported the students to think critically. It seemed to be that the participant teachers had learned by sharing and discussing their understanding and teaching experience. These research findings are relevant to teaching strategies that support students' CT suggested by several studies such as Wolcott (2000), Schwartzer (2005), and Taitelbaum *et al*. (2008). At the end, they strengthened and improved their knowledge about CT and teaching for CT. Attending professional learning activities in general usually provides participants to get new information and knowledge from discussions with each other (Hanpipat, 2010).

The participant teachers exchanged one's ideas about what might hinder or facilitate utilizing CT activities in their classrooms. As Ms. Tawan addressed in post-class interview that engaging activities during the workshop contributed them to realize that teaching for CT could be embedded in their regular classroom activities and tasks. All three teachers seemed to increase understanding of teaching for CT. On the other hand, they mentioned about teaching for subject coverage lesser comparing to before the PD activities. The research finding in this section suggested that all participant teachers possessed better understanding and awareness in teaching for CT as a result of their participation in the PD program.

The Improvement in the Use of Questions, both Quantitatively and Qualitatively, to Promote Students' Meaningful Learning and Thinking

Asking questions was one teaching strategy that all participant teachers perceived as a good way for developing students' CT. At the beginning of the study, the participant teachers seemed not to ask questions in the way that promoted students' CT. Most of the questions were yes-no questions and short-answer questions that required only memorization. After the PD activities, the participant teachers seemed to use more questions with better quality. They used better questioning techniques which encouraged their students to think about the answers as well. There were various types of questions: open-ended, short-answer, reason-supported, and decision making. Those types of questions would promote students' CT (Stillings and Wenk, 1999; Wilson, 1999; Tongpan *et al*., 2009). Ms. Tawan and Mr. Artid showed significant improvement in questioning techniques that promoted students' CT. They gave students time to think about the answers. They also challenged the students to answer questions by calling individual students or groups of them to answer. Ms. Tawan asked other similar questions that were easier than the intended questions to help students gaining basic knowledge before getting back to the intended questions. These teaching strategies are helpful to motivate students to think (Zohar and Schwartzer, 2005). Ms. Tawan and Ms. Ratree challenged their students to answer questions by calling for volunteers and giving them extra marks. These two teachers stated in their post-class interviews and reflective journals after the PD activities that they paid more attention to the use of questions as they learned through the professional learning activities in the PD activities. In addition, Mr. Artid stated in the post-class interview of the equilibrium constant (K_{eq}) lesson that he should use more questions and call the students to answer by groups or individuals to solve chemistry problems. Eventually, it appeared that all teachers gradually improved on raising a number of questions with questioning techniques to motivate students to answer critically.

The Improvement in Implementation of CT Activities and Tasks that Promote Students' Interactions and Participation

The findings, at the beginning of the study, showed that the participant teachers paid little attention to what the students learned from the lessons and how much the students paid attention to classroom activities by participating actively. For example, Mr. Artid and Ms. Ratree provided laboratory lessons for students, but they did not motivate the students to contribute to experiments as good members of groups. On the other hand, the findings from classroom observations after the PD activities showed that the participant teachers learned how they would encourage students to interact and participate in classroom activities through a variety of teaching techniques such as assigning small group activities, having quizzes before teaching in order to examine students' basic knowledge or assess what they learned from previous lessons, asking for volunteers to draw solutions of Chemistry problems on the blackboard, engaging in discussion based on experimental results, and using questioning techniques which were similar suggestions about ways to engage students in learning activities by Simpson and Courtney (2008) and Malamitsa *et al*. (2009). Ms. Tawan stated that analyzing classroom activities with the other participant teachers during the PD program improved her techniques for challenging students' interactions and participations in classroom activities (e.g., calling them to identify the differences and the similarities between two sets of compounds, and drawing Lewis's structures of some covalent compounds on the blackboard). Mr. Artid and Ms. Ratree realized that they had CT tasks provided for the students. As Mr. Artid said in the final interview, "I perceive that I am thinking more about learning activities and tasks before teaching. If I have enough time, I will let them do experiments as much as possible. In any case, I will involve them in thinking activities such as using written tests before and/or after lessons" *(*Interview: January 20, 2010). Mr. Artid and Ms. Ratree did assign their students to conduct experiments in ways that required more participation than they did before attending the PD activities such as planning experiment procedure before entering the lessons, discussing data and evidences based on their experiment. Then, the students drew conclusions and wrote experimental reports. Regarding Ms. Ratree, she implemented CT activities in her classes than ever before. For example, she asked her students to solve chemical reaction problems in small groups after she presented the solutions for similar and easier problems. Ms. Ratree also gave her students some exercises that required comprehensive and high cognitive knowledge. Some of the exercise items directed the students to write their supporting ideas which she was observed very little such activities before. In doing so, all of the participant teachers appeared to be better in utilizing CT activities to promote students' CT after participation in the PD program.

The Development in Assessment Practices for Determining Students' Understanding and Thinking Abilities

The participant teachers appeared to improve their assessment practices continuously throughout their participation in the PD program. For example, they mentioned that they would like to determine students' understanding and thinking abilities while they were doing classroom activities, which they independently indicated in the paper-and-pencil test before the PD activities. Ms. Tawan seemed to evaluate her students' understanding with both formative and summative assessments. At the beginning of the study, Ms. Tawan used students' memorized knowledge and closed-ended questions to determine their prior knowledge and basic understanding related to the teaching concepts. Then, she gradually included CT questions that required students' reasoning skills to solve. The participant teachers observed students' learning behaviors while the students were solving Chemistry problems collaboratively within small groups. Moreover, Mr. Artid and Ms. Tawan assessed students' scientific skills and scientific process using rubric scores. In addition, all of the participant teachers employed CT activities with their students which allowed the teachers to assess students' progress in learning and thinking. Most of tasks required students to use complicated knowledge and high cognitive skills to complete them. Furthermore, the participant teachers also included written tests in the final examinations, which measured how students solve difficult Chemistry problems using CT. According to Stillings and Wenk (1999) and Malamitsa *et al*. (2009), this teachers' assessment practice is able to assess students' CT. The students had to present step-by-step solutions. For multiple-choice tests, they also emphasized on assessing students' more complicated knowledge than what they did in the midterm examinations.

In summary, the cross-case analysis of all the teachers who participated in a PD program on CT suggested that all of them illustrated gradual increase of their understanding of CT and teaching practices for CT in Chemistry. In addition, analysis of the evidences from interviews, classroom observations, reflective journals, and documents related teaching suggests that they also improved on how to develop and assess students' scientific skills and scientific process skills. Their students also illustrated increasing engagements in classroom activities comparing to the findings before the PD activities. The students of all three teachers discussed and shared their ideas about Chemistry problems with their group members, and then they showed their solutions on the blackboard. Comparing to before the PD activities, almost all of the students of Mr. Artid and Ms. Ratree also increased in doing experiments. Their classrooms appeared to shift from passive classrooms to active classrooms compared to before and after PD respectively, in which students were expected to develop CT skills. It was a very good sign that all of the participant teachers mentioned lesser about teaching for covering a huge content of knowledge, after their participation in the PD program. They no longer only taught students in order to succeed in examinations, but they were aware of nurturing the students' thinking abilities as well.

According to all above results, it is necessary to consider interrelated factors that might affect the participants' learning and their changes in understanding of and teaching practices for CT. Looking back to each participant teachers' definition of CT, the findings showed that there was relationship between the definition of CT and classroom activities for CT in the participants' minds. It seemed that even though all of the participant teachers mentioned a variety of learning activities that promoted students' CT, but they were superficial and did not have clear ideas how to implement such activities. According to previous researches related to this area, teaching for CT was characterized by encouraging students to have more interactions and active participation in hands-on and minds-on activities, such as asking productive questions, cooperative learning, a small group discussion, 5 E-learning cycles, inquiry-based laboratories, solving problems, and linking knowledge to real life (Wolcott, 2000; Barak *et al*., 2007; Pitagsalee *et al*., 2007; Willingham, 2007; Simpson and Courtney, 2008; Malamitsa *et al*., 2009; Buntod *et al*. 2010). In laboratory classes, the participant teachers had limitation of ways to promote students' CT. Malamitsa *et al*. (2009) suggested how to incorporate experiment lessons to promote students' CT as if the students were following the experimental steps of a scientist. It has been said that the experiments should involve students in defining problems, planning procedures, collecting and interpreting data, raising arguments, evaluating actions, and reporting conclusions. These activities were illustrated by the participant teachers at a little level before their attending the PD activities.

Considering the background of the participants, it is reasonable to say that the teachers' experience in professional development activities related to teaching for thinking appears to have an effect on the participants' teaching for CT. Ms. Tawan had attended a seminar about teaching science for higher-ordered thinking prior to this PD program on CT. On the other hand, Mr. Artid and Ms. Ratree revealed during their initial interviews; they have had no opportunities to participate in professional learning activities related to CT before this PD program. They only attended workshops on designing instructional media. The analysis of interviews with teachers before the PD activities implied that Ms. Tawan held better understanding of teaching for CT than other two teachers. As result from the initial interview, Ms. Tawan defined CT close to theoretical conceptualization than other two participants. She also was able to raise some activities that engaged students in thinking critically such as analyzing experimental data and drawing conclusions based on the experiment. This suggested that a number of teachers' attending professional learning activities may impact teachers' conceptualization of CT and teaching for CT because each PD program typically provided intensive experiences and knowledge in the context of relevant professional development.

Regarding another factor, throughout the PD program's collaborative study with the participant teachers, the researcher found their distinct attempt to learn teaching for CT. Ms. Tawan presented actively in learning about how to teach for CT than the others. She searched for the meaning of CT and teaching for CT at the beginning of the study while Mr. Artid and Ms. Ratree did not do their further seeking for the concepts of CT or teaching for CT out of provided PD activities. In addition, the researcher noted that the participants' goals of teaching seemed to reflect the teachers' awareness of teaching for CT. Ms. Tawan said clearly that she aimed to promote students' CT whereas the other participants wanted to develop students in content knowledge. Therefore, encouraging the teachers to participate in the professional development activities related to teaching for CT is necessary.

In summary, over all of the above research findings about the teachers' understanding of teaching for CT suggested that the participant teachers, before the PD activities, had little in providing a full definition of CT. They also held an unclear understanding about how to implement classroom activities in the ways that promote students' CT. Problematically; they possessed a lot of perceptions that seemed to be barriers for employing CT activities in their classrooms. Those perceptions include: a) recognizing the importance of CT without integrating CT tasks in their classrooms, b) perceiving CT tasks as a waste-time, and c) perceiving CT tasks as only appropriate for high academic achievers, not for low academic achieving ones. The above findings might effectively predict how teachers who participated in the PD program did in their actual teaching. Furthermore, the teachers' understanding of CT appeared to be a key factor in the progress of the professional training based on provided activities in the PD program. Prior studies also suggest that teacher understanding would also affect how the participant teachers apply knowledge from the PD program in their classrooms (Wolcott, 1998; Zohar *et al*., 2000; Torff and Sessions, 2006). According to above results before they attended the PD activities suggested that the participant teachers' understanding of teaching for CT were low and seemed to hinder their own capacities in teaching for CT. These their understandings also characterized how they practiced in their actual classrooms (Watts *et al*., 1997; Zohar and Dori, 2003; Veal, 2004; Juntaraprasert, 2007).

The Factors that Influenced the Teachers' Improvement on Teaching for Critical Thinking

In this study, we aimed to determine on the factors that greatly influenced the teachers' improvement in teaching practices for CT. The findings appeared that some factors facilitated the participant teachers' teaching practices for CT while some factors were obstructing them. Two main factors were considered, including the main characteristics of the PD program and the participant teachers' background and teaching environment. The following paragraphs illustrate how the factors had influenced the teachers' teaching practices for CT.

The Main Characteristics of the PD Program

This PD program was designed with the goal of improving the participant teachers' teaching practices for CT. The PD program was designed as a long-term program that required an academic year of participation. It focused on collaborative learning via discussions and reflections based on teachers' background. It provided an intensive workshop about teaching for CT in Chemistry. It also took the participant teachers' background and environment into account.

The first characteristic of the PD program was long-term participation. The participant teachers said that one academic year was very helpful for them to gain experience in learning and changing teaching practices in the context of teaching for CT. As Ms. Tawan said, the school curriculum required special science program students to experience learning and thinking for scientific procedure as well. She used to attend a seminar related to teaching science for higher-ordered thinking (HOT). However, the seminar was held only for a day and she only got to listen to the concepts of teaching for HOT. At the end, she only knew what HOT was and what its basic concepts were. She felt that the time was too short time for learning and applying knowledge into real teaching practices. Mr. Artid and Ms. Ratree also stated similar ideas. They had no experience in any professional training related to teaching for CT before. All three participant teachers showed gradual improvement in understanding of teaching for CT and teaching practice for CT throughout participation in the PD program. For example, Ms. Ratree said in the final interview that participating in the PD program encouraged her to be an active teacher. She got better in using teaching techniques to motivate students to interact with her in class and designing classroom activities that were engaging.

Another characteristic of the PD program was that most of activities inside the PD program encouraged the participant teachers to be involved in collaborative discussions and reflections based on their understanding of teaching for CT and their own teaching experience. Sharing different experiences led them to improve on teaching practices for CT, as all three participant teachers agreed, based upon their final interviews and reflective journals, that they learned greatly by exchanging teaching experience with each other. As Ms. Tawan said during the second group meeting that she learned about classroom activities that might promote students' CT via discussions and reflections about the classroom activities of the other participants'. She realized that, sometimes, teachers could motivate students to think critically using the same classroom activities they used before. For instance, normal lectures could also promote students' CT if teachers asked some cognitive and open-ended questions. Ms. Ratree also shared that, often, she assigned students to conduct experiments, but only a small group of the students paid attention to do it. Throughout meeting with the other teachers, she addressed that it should be better if she made sure that every student took part in the experiments. Each student should be involved in all steps of scientific process. She also mentioned that a good relationship between teachers and students was very important for developing active classrooms. Mr. Artid agreed with Ms. Ratree, he mentioned that it was very difficult for him to direct his students to do classroom activities. Most of Mr. Artid's students seemed to be passive learners who just sat and listened to the teacher without responses or answers. Mr. Artid reflected on his class that he was not close to his students. The students also seemed to pay little attention to what he was teaching. So, he wanted to create a good relationship with his students. He believed that it would help him engage the students in classroom activities that promoted them to think critically further. It could be said that the participant teachers learned through exchanging ideas and experience in teaching with each other. They also got some ideas from the PD, such as motivating students to think and answer to questions by calling individuals or student groups and giving appropriate wait-time for answers, asking for volunteers to present solving chemistry problems on the blackboard as well as motivate other students in the classes to share ideas based on the problems and encouraging the students to do experiments. These findings suggested that all participant teachers had improvement on how to conduct their own classroom activities in order to develop students' CT.

Another important characteristic of the PD program was the workshop on teaching for CT in Chemistry. Professional training activities appeared to be very helpful for the participant teachers in improving knowledge about teaching techniques and designing learning activities related to teaching for CT. Ms. Tawan reflected that she gained good experience from attending the PD activities. As Ms. Tawan said in her reflective journal and in an interview, I never thought about categories of scientific knowledge such as facts, concepts, laws, and theories, but I learned about them here. There are many activities that enable me to apply teaching practices for CT to my classroom, such as teaching students how scientists get scientific knowledge, learning science by following steps of those scientists, and indicating learning objectives with high cognitive levels. Also, another good thing was that I was engaged in solving cognitive tasks in Chemistry, so I learned what difficulties the students might face when they performed the tasks.

(Ms. Tawan's reflective journal: February 8, 2010)

I also learned about using scientific techniques such as making a half drop of titration when the reaction was closed to the end. Engaging in learning activities like POE [Prediction-Observation-Explanation] activity is a good example. I applied it into my class to motivate students to think and predict what will happen if…

(Interview: January 27, 2010)

Ms. Ratree also talked about how the workshop benefited her. She used to think that it was normal to organize classrooms the way she did before. She could accept when there was only a small group of students who did experiments and gave the experimental results to the whole class. However, reflections by the other participants on her classrooms through the video-recorded presentation during the workshop motivated her to improve her classroom activities by involving all students in experimental procedure. After the PD activities, she appeared to organize her active classroom where increased a number of the students participated in experimental procedure and responded to her teaching such as solving a rate of chemical reaction problems with their groups and presented steps to solve the problem for the whole class. Ms. Ratree also said about the improvement in her questioning techniques as a result of attending the PD activities that,

Actually, I often asked students questions during lessons. But, I did not know how to promote students to think via such questions. The workshop provided me ideas about techniques to raise questions in order to motivate students to answer and express their thinking. In the present, I use “Why” questions more often and I give them a moment to think about the answers. This makes my students listen to me better and interact with me more.

(The second group meeting: January 27, 2010)

I like activities in the workshop in which we (the participants) had opportunities to deal with cognitive tasks related to Chemistry and to design learning activities collaboratively. So, I should be able to identify which parts of the lessons seemed to engage students in cognitive tasks. Before, in my teaching practices, I usually set up experiments for students. After attending the workshop, I realized the importance of involving all students in experimental procedure as when we all had to solve Chemistry problems to identify the types of plastic seeds. At that time, we were thinking.

(Ms. Ratree’s reflective journal: February 4, 2010)

Mr. Artid had similar effects on his development in teaching for CT after attending the PD activities. It was regrettable that Mr. Artid could not attend the first day of the workshop. Because of that, he did not get to experience a variety of learning activities and teaching techniques, which the participants could apply with their actual classrooms. However, Mr. Artid attended the last two days of the workshop, which were also helpful to him in developing his teaching practices in the context of teaching for CT. Mr. Artid said that watching the classroom practices of the participants through video-recorded presentations made him concerned about teaching techniques that help promote students’ CT. As Mr. Artid stated in an interview about his teaching practices after the PD activities,

Researcher: How did the PD activities benefit you?

Mr. Artid: It helped me become more active in planning lessons and implementing teaching practices for CT.

Researcher: What do you mean by that?

Mr. Artid: For example, discussion with other participants in the PD activities about techniques that promoted students to think during lessons guided me to apply the techniques to my classes.

Researcher: How do you improve in the ways that promote students' interactions and expression of their thinking?

Mr. Artid: Personally, I actually realized that my students were quiet. I could not determine whether or not they were following me. A research advisor suggested to me that I must establish a good relationship with them. I might call their individual names or groups to answer or to solve a cognitive task. In practice, I feel that I am more confident to conduct my lessons.

Researcher: Why do you say that you have improved on this teaching practice?

Mr. Artid: The students looked like they were listening to what I was teaching.

Researcher: How about their critical thinking?

Mr. Artid: I think that they are good. Once, I called a pair of each group to present solutions of chemical reaction problems and they could do it. That was very surprising to me.

(The final interview: January 20, 2010)

It appeared that the teaching practices for CT of the three participants were positively affected by the PD activities. They shared their teaching experiences and prior understandings about the meaning of CT and teaching for CT during the PD program. In the end, after they discussed about teaching for CT based on their own Chemistry teaching and on reading some documents related to teaching for CT, they gained similar understanding and teaching practices for CT. The participant teachers also mentioned about doing an experiment that it did not only let students do the experiment written in textbooks. They realized that it was also very important to challenge students to be involved throughout an experimental procedure. Students would acquire scientific knowledge and develop scientific skills and thinking abilities by thinking about learning objectives, planning, conducting, discussing, and drawing conclusions based on the experiment. The participant teachers said that designing a lesson together and reflecting on the lesson were very useful for each of them. They got ideas about how to design learning activities to promote their own students' CT in their actual classes. These findings suggested that professional learning activities in the PD program were useful to increase the participant teachers' capacities in teaching for CT in Chemistry.

The Participant Teachers' Background and Teaching Context

In order to be successful in professional development training, it is normally important to consider the participants' background and teaching context. The researcher needed to know the influencing elements that characterized the development of individual participant teachers, including prior understanding and experience about CT and teaching for CT, and background of their students and the teaching context. Ms. Tawan presented gradual improvement in her capability of teaching for CT from the beginning to the end of the study, while Mr. Artid and Ms. Ratree could realize their obvious improvement after attending the PD activities. The following paragraphs suggest how differences in the participants' background and teaching context resulted in individual development in teaching for CT.

The Participant Teachers' Prior Knowledge about CT and Experience in Teaching for CT

Good understanding can pave the way to good practices. The three participant teachers were different in their prior understanding about CT and experience in teaching for CT. Thus, it could be suggested that their different prior understandings influenced their individual results of participating in the PD program. At the beginning of the study, Ms. Tawan possessed better understanding about CT and teaching for CT than the other participant teachers as described in Chapter IV. Ms. Tawan also seemed to be more familiar in teaching for CT than the others. She used to attend a seminar related to teaching for higher-ordered thinking in science. Mr. Artid and Ms. Ratree had experience in professional development activities about using instructional media, but they had no experience in teaching for critical thinking. Therefore, it could be hypothesized that the participants who had basic understanding about teaching for CT might perform better in teaching for CT than the ones who had no experiences in this teaching area before.

The Background of Students and the School Context

The background of students and the school context were mentioned by the participant teachers to have influences on teaching for CT. The participant teachers mentioned that the special science students were certainly more active learners than the students who were enrolled in ordinary science program. Furthermore, the participant teachers perceived that the special science program students possessed higher abilities in learning and dealing with highly cognitive tasks, while the other group of students was judged that they were not appropriate in dealing with such cognitive tasks. This perception appeared to influence what learning activities the participants provided for their students. The school context also had effects on the teachers' teaching practices for CT. The schools of the participant teachers' provided enough facilities to support students to have meaningful learning in Chemistry if only the participant teachers had enough capabilities to apply such facilities in that way. However, limitation of time became a dominant factor that influenced the participant teachers' teaching practices, based on what they said in the interviews. All of the three participant teachers faced this problem. The schools often had other activities that required students to participate. At the end, time for teaching Chemistry was shorter than the initial schedule. The participant teachers decided to employ lectures instead of hands-on activities which seemed to take more time. Therefore, these three factors should be considered by education scientists and professional developers who want to enhance teachers' teaching practices in the context of teaching for CT through further PD activities.

Summary

In summary, the results of the participant teachers' teaching for CT prior to attending the PD activities suggested that all of the teachers had limited teaching for

CT. They seemed not to be aware of teaching for CT in their classrooms. While CT activities were perceived as a waste-time, the teachers also stated that CT activities and CT tasks were for only students who were seen as a group of high achieving learners rather than a group of students who were lower achievers. In practice, the participant teachers appeared to teach for covering content knowledge and national examination throughout teachers' talk and lecture. They presented little engaging students in learning activities. They used memorizing questions and sometimes answering to the questions themselves. According to the findings of individual teachers' teaching in Chapter IV, all teachers appeared to express the pedagogical development of teaching for CT to small extent including: questioning techniques, and learning assessment. While Mr. Artid and Ms. Ratree expressed teaching for CT to small extent comprising of meaning of CT, awareness of teaching for CT, goals of teaching, classroom activities, and strategies to engage students in learning activities; Ms. Tawan showed teaching for CT to some extent for goals of teaching, teaching preparation, classroom activities, strategies to engage students in learning activities. Ms. Tawan and Ms. Ratree provided tasks and activities seeming closed to teaching for CT to some extent.

The results after the PD activities suggested that the participant teachers had various increases in teaching for CT. All of the teachers gave a greater definition of CT and presented awareness of teaching for CT by setting goals of teaching for CT and preparing learning activities in a way that promoted students' CT. They also improved in employing teaching strategies to engage students in learning activities and giving tasks that required students to discuss and express their thought based upon reasons and evidences. However, classroom activities conducted by all of the participant teachers represented a major of content-driven classrooms where the teachers would skip experimental sessions or complicated tasks requiring very much time to complete them. It was hypothesized that several important features of the PD program, such as long-term participation of an academic year and concerning to teachers' background and teaching context contributed to the changes in the participant teachers also.

CHAPTER VI

CONCLUSIONS AND IMPLICATIONS

Introduction

This chapter presents the conclusions and implications of the study. The chapter reiterates the context of the study, reviews briefly the research methodology, and reports on the main findings on the PD program and the participant teachers' teaching for CT. The implications of the study are discussed at the last section of the chapter.

Review of Context of the Study

The main emphasis of Thailand's educational reform is the construction of a knowledge-based society (Office of the National Education Commission, (ONEC), 2002). Correspondingly, the main goals of science teaching and learning in Thailand are to develop students in abilities to solve problems, make decisions, think critically and do science process and skills (Ministry of Education, 2001; IPST, 2001). While difficulties in critical thinking and solving problems of Thai students had been reported (**ONESQA, 2003;** Pitagsalee *et al*., 2007), for enhancing students' abilities to think critically, teachers' understanding of and teaching practices for CT are seen as important factors. Teachers' teaching practices affect students' learning and thinking (Weinberger and Zohar, 2000; Zohar and Schwartzer, 2005; Roehring and Garrow, 2007). In Thailand, there are a few seminars or single workshops on teaching for CT. Thai teachers still need necessary competencies including new types of pedagogical knowledge, new learning strategies, assessment and evaluation practices, and integrated teaching to improve students' learning (Pillay, 2002). In current study, the attention therefore is paid to teachers' understanding of and teaching practices in the context of the promotion of students' CT in chemistry.

Review of Research Methodology

The interpretive case study aimed mainly to determine how the PD program enhanced three chemistry participant teachers' understanding of and teaching practices for CT. Consequently, the study included two main research questions:

1) What are chemistry teachers' prior understanding of and teaching practices for CT?

2) How does a PD program affect chemistry teachers' understanding of and teaching practices for CT?

The use of case studies was conducted with three voluntary chemistry teachers. The participant teachers were named by pseudonyms consisting of Ms. Tawan and Mr. Artid teaching at Namsai Wittaya School, the school for only female students, and Ms. Ratree teaching at Tonnam Suksa School, the co-ed school. These two schools are a special large type of schools which there are about three thousand students for each. These two schools locate at Nonthaburi Province, a central part of Thailand. Purposively, all participant teachers were followed their teaching chemistry in different concepts with students in different grade levels: Ms. Tawan for grade 10, Mr. Artid for grade 11, and Ms. Ratree for grade 12. In addition, the participant teachers had differences in teaching experiences, background knowledge about teaching for CT prior to participation in the study. Their students also had different backgrounds.

Data collection took place over a whole academic year in 2009. The PD program had two main phases including: Phase I and Phase II. Phase I of the PD program aimed to design the professional learning activities having two stages. Stage 1of Phase I examined participant teachers' prior understanding of and teaching practices for CT in the actual classrooms. In order to gather useful data, multiple methods for collecting data including classroom observations, post-class interviews, semi-structured interviews, the pre-workshop questionnaire, and document analysis were employed. Stage 2 of Phase I designed professional learning activities in the PD program and methods to follow up the participant teachers' development in teaching for CT. The designed activities were concerned with the combination of the gathered data from Stage 1 and a review of literature related to teaching for CT. This phase of the PD program was conducted during the first semester of academic year 2009. Prior to starting the second semester of the academic year 2009, the participant teachers attended the workshop on teaching for CT (as presented in Chapter III). After the workshop, Phase II of the PD program was conducted. This phase aimed to implement and evaluate the PD program. Data collection in this phase involved classroom observations, post-class interviews, semi-structured interviews, group meetings, document analysis, and reflective journals.

In order to answer the above two research questions, a case and a cross-case analysis were undertaken. The researcher transcribed the interviews and the classroom observations of individual teachers. The researcher then read transcribed data combined with data from the pre-workshop questionnaire and teaching documents leading the researcher to the important findings of participant teachers' prior understanding of and teaching practices for CT. Phase II of the PD program produced some data useful for analyzing the changes of participant teachers' understanding of and teaching practices for CT. The analysis also sought to identify those factors which facilitated or hindered the development of participant teachers' teaching for CT. Furthermore, the features of the PD program that supported the participant teachers in "learning to teach" related to the context of teaching for CT were suggested. The following paragraphs presented the conclusions of the study.

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Participant Teachers' Prior Teaching for Critical Thinking

Prior Understanding of Teaching for Critical Thinking

In order to address the first research question, participant teachers' prior understanding of and teaching practices were determined. The participant teachers perceived CT as ability to answer to questions with reasoned, analytic and reflective thought, and linking chemistry knowledge to real-lives. One of the participants, Ms. Tawan, appeared having more familiar with understanding of teaching for CT than other two teachers. This might be a result of her attending a one day of seminar about teaching science for higher-ordered thinking. All participants viewed that teaching for CT involved asking students questions and doing scientific experiments. In the case of Mr. Artid, teaching for CT was represented by solving chemistry problems, and doing exercises based on the chemistry textbook. While Ms. Ratree, pointed to integration of various knowledge subjects. According to these findings, the teachers exhibited differences in their understanding of teaching for CT at the beginning of the study and prior to participation in the PD program designed here.

The research findings also illustrated that before the PD activities the participant teachers recognized the importance of CT for students' learning and lives, but they perceived CT activities as a waste time, and a separation away from chemistry knowledge activities. Also, CT tasks were for only high academic achievers; not for the students who were the low academic achievement ones. The participant teachers decided to skip already designed CT activities whenever they faced with time and content coverage issues. Although the teachers could name teaching methods seen as promoting students' CT, they had a hard time describing "how to" employ such teaching methods in ways contributing to develop students in CT. For example, in practice the participant teachers used almost all of yes-no and memorizing questions requiring short answers. Similarly, Ms. Ratree suggested that it should link classroom knowledge into real-life for developing students' CT, in practice she focused on covering content knowledge rather emphasis of linking knowledge into real-life.

Teaching Practices for Critical Thinking

The research findings based upon classroom observations and interviews before the PD activities found that the participant teachers conducted their classrooms seeming to rely upon traditional teaching methods such as lecturing, completing exercises, and doing experiments written in the textbooks with less students' designing the experiments and discussions with the whole class. Theoretically, doing scientific experiments to promote students' CT should provide the students to identify a problem, generate hypotheses, design and conduct an experiment, analyze and interpret data, and draw conclusions based on the experiment (Bailin *et al.*, 1999b; IPST, 2001; Pitagsalee *et al.*, 2006; Malamitsa *et al.*, 2009).

In terms of engaging students in CT, Ms. Tawan employed teaching strategies to engage her students such as calling for volunteers to demonstrate scientific experiments, and referring to academic competitions. Two of the participants, Mr. Artid and Ms. Ratree appeared to do little to encourage students' interaction and participation in CT classroom activities. Mr. Artid seemed to ignore students' behaviors altogether. Though, the participant teachers perceived that asking questions as a good way to promote students' CT, they always raised yes-no and remembering questions. They did not use students' responses as a driving force for CT. They tended to reply to challenging questions themselves. In experiment lessons, the participant teachers rarely engaged their students in inquiry-based learning; they seemed not to determine students' growth in scientific skills, scientific processes, abilities to solve chemistry problems, and CT during classroom activities; the participant teachers concentrated more so on assessing students' chemistry knowledge by utilizing paper and pencil tests. In conclusion to the first research question, it could be said that the participant teachers possessed a limited understanding of and teaching practices for CT before they experienced the workshop on teaching for CT. Correspondingly, their lessons overemphasized traditional didactic based-teaching where memorizing content knowledge was the focus. They, therefore, in the opinion of the researcher, still need to engage in long-term professional learning related to teaching for CT.

Possible Influences of the PD Program on Participant Teachers' Understanding of and Teaching Practices for Critical Thinking

With regard to the changes in participant teachers' understandings and teaching practices for CT after attending the PD activities, the teachers appeared to possess a better definition of CT comparing to the beginning of the study, and as exemplified in interviews and classroom observations, they appeared to have an increase in awareness of teaching for CT. According to classroom observations, all three teachers had development in asking questions both a number of questions and questioning techniques to motivate students to answer their questions. The questions also presented cognitive questions requiring critical thinking abilities. After attending the PD activities, the teachers appeared to have open-ended questions, asking students to support their answers, present ideas, and make decisions. The participant teachers used techniques taught in the workshop to encourage the students to think about the questions such as giving them wait-time, using similar and easier questions then back to original questions, calling individual students or groups, calling for volunteers, and giving praising words.

The participant teachers, furthermore, appeared to improve in ways to engage students' active participation by doing small group activities, asking for volunteers to draw solutions of chemistry problems on the backboard, and engaging in discussion based on experiments. In addition, incorporation of teaching Chemistry related to promote students in thinking critically such as: seeking particular topics and doing presentation based on the topics, using quizzes before teaching, challenging chemistry problems, identifying the differences and the similarities between two sets of compounds, drawing molecular structures of covalent compounds, and planning procedures of experiments. Furthermore, the development in assessment practices was apparent after attending the PD activities. Now, students' learning was assessed during taking class and after teaching by using CT questions, observing, and scoring a rubric that was meant to assess students' scientific skills and CT abilities.

The Factors that Constrain or Facilitate Participant Teachers' Teaching for Critical Thinking

Throughout the study, Ms. Tawan presents what appeared to be a gradual improvement in her capacity to teach for CT from the beginning to the end of the study while Mr. Artid and Ms. Ratree perceived their development in this regard after attending the PD activities. Four major factors are recognized as possible influencing participant teachers' understanding of and teaching practices for CT in the study. The factors are 1) the essential features of the PD program, 2) the participant teachers' prior knowledge and experience about CT and teaching for CT, 3) students' background and the school context.

The first factor was regarding the essential features of the PD program that may have facilitated the participant teachers' teaching for CT in the study included 1) holding on a whole academic year of participation as a long-term PD program, 2) focusing on collaborative learning through discussions and reflections based on the participants' understanding of teaching for CT and their teaching experiences, 3) providing an intensive workshop on teaching for CT in Chemistry, in which the participant teachers would gain experience in teaching in the context of teaching for CT in Chemistry, 4) and employing PD activities based on the participant teachers' backgrounds and teaching experiences. Therefore, the participant teachers gain value learning to teach for CT through exchanging teaching experience with each other.

Regarding the second factor, participant teachers' prior knowledge and experience also may have had an effect on their teaching for critical thinking. Ms. Tawan possessed better understanding about CT and teaching for CT than other participant teachers prior to the study. Mr. Artid and Ms. Ratree had experiences in professional development activities about using instructional media, not focusing on teaching for critical thinking. After the PD, Ms. Tawan also appeared to teach for CT better than the other two participant teachers, according to the researcher. Therefore, one might be suggested that the participants who have experienced related to teaching for thinking might illustrate a great development in teaching for CT.

The last factor was students' backgrounds and the school context. For instance, the special science program students were viewed as more active learners, who possessed higher abilities in learning and dealing with high cognitive tasks than the students who were enrolled in ordinary science program. The school context also affected the teachers' teaching practices for CT. For example, the school with enough facilities could better support students in learning about Chemistry. Limitation of time and additional school activities could lead the participating teachers to decide to use lecturing method instead of hands-on and minds-on activities, which seemed to take more time. Therefore, science educators and professional developers who want to enhance teachers' teaching practices in the context of teaching for CT through further professional development activities should consider these three factors.

Implications of the Study

Implications for Professional Development

The PD program appeared effective in enhancing the participant teachers' understanding of and teaching practices for CT in Chemistry. As qualitative research of case study, the generalization of the research results is not intentionally in the scientific sense. The study deals with three cases of chemistry teachers only. However, this way is helpful for the study to gain thick information based upon the context of the study. Therefore, the information contributes the researcher to interpret the meaning of what happens in the unit of the study.

In addition, the PD program in this study was designed by using multiple strategies in order to support professional learning along with awareness of context of the participant teachers. The advantageous features of the PD program which support the participant teachers to learn how to teach for CT are the: 1) long-term participation in which the participant teachers constructively learned how to teach for CT from working collaboratively with each other, 2) taking the participants' prior understanding of teaching for CT into account to design professional learning activities, 3) emphasizing on collaboration between the participants and the researcher in order to share teaching experience through discussions and reflections on teaching, and 4) providing professional learning support by allowing the participant teachers to watch the recorded videos of their actual classrooms and to deal with sample cognitive tasks or activities to help them learn about the difficult parts and the easy parts of such tasks.

The other important factors that affected the participants' teaching for CT based upon knowledge gained from the PD program appeared to be limitations of time, additional school tasks and activities, schools' and parents' expectations, teachers' experience related to teaching for CT, and the students' background. Based on those factors, the study suggested that the changes of the participating teachers could be characterized by "external factors" (e.g., teachers' working conditions) and "internal factors" (e.g., teachers' prior understandings and experience related to teaching for CT). It is pretty straight-forward for science educators and professional developers to identify and categorize such factors.

Implications for Chemistry Teachers in Teaching for Critical Thinking

Teaching for CT is gaining popularity in regular school subjects nowadays while chemistry education is facing many problems, such as students' low academic achievement, students' negative attitudes, and teachers' lack of subject knowledge and the knowledge about how to teach for meaningful learning. One key problem is that Chemistry teaching relies too much on covering knowledge within the textbooks, which contain too much content. It is impossible for teachers to make students remember such huge amount of content within an academic year. Teachers need to nurture students' critical thinking abilities as well as helping the students understand key concepts. Teachers have to shift from teacher-directed classrooms to student-centered classroom. They should design their regular classroom activities in a way that promotes students' thinking abilities. An important thing is that participation in professional development activities always supports teachers' profession. Evidently, the teachers in this study, who had experience in attending a seminar on teaching science for HOT, illustrated gradually growing teaching practices for CT. It is significant for the development of teachers' profession that they are voluntary and willing to develop their teaching skills. These factors will let the teachers be open-minded in collaborative learning through sharing their teaching experience, discussions, and reflections based on their teaching context. Then, they can apply the knowledge obtained from participating professional learning activities to their actual classrooms after finishing the PD program.

Recommendations for Further Studies

The study was productive in enhancing the participant teachers in understanding of and teaching practices for CT. They gradually improved their regular teaching in a way that promotes students' CT. As qualitative research using case studies, the generalization of the results is not in case. The study dealt with three chemistry teachers only. Considering insight each participant in this study, there were differences in some external factors (e.g., school context and students' background) and internal factors (e.g., teachers' prior understanding of teaching for CT and teachers' expectations from participation in professional development activities). The study thus suggests that a further study should investigate how individuals learn to change their understanding and teaching practices when the above factors are involved. Sustains of participant teachers' change and development should be determined as well. Furthermore, the research findings found that the participant teachers had improved in a small level of designing several learning activities and assessment practices in the context of teaching for CT. Therefore, a further study should focus on supporting teachers in areas of designing CT activities and ways to assess students' CT.

This study dealt with the participant teachers only for an academic year. It is valuable to investigate effects of the PD program on teachers' changes by following professional learning for longer period of time. The further study may include research questions such as "Do the teachers still apply their knowledge gained from the PD program to their teaching practices in the second or the third academic year after attending the PD program", or "Do the teachers have continuous improvement in their teaching?. Because this study concentrates on enhancing professional development in the context of teaching for CT, a major attention is paid for teachers' changes in understanding and teaching practices. Therefore, it is productive if future studies would investigate the effect of teachers' changes on students' learning and thinking.

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APPENDICES

Appendix A

Semi-Structured Interview Protocol

Semi-Structured Interview with Teacher Protocol (Initial interview)

Teachers' Understanding about Teaching for Critical Thinking

Teacher: ____________________________ School: __________________________

Date: _______________________________ Time: ____________________________

Interviewer: ____

Interview Context: ____

1. What are your goals of development students in learning Chemistry?
2. What are the key factors you relying on goals of teaching Chemistry?
3. What is CT? How do CT benefits students?
4. Do you consider teaching chemistry for CT? Why? How?
5. Is it possible to integrate teaching for CT in Chemistry? How? (Give me an example)
6. In your teaching, how did you plan your classroom activities?
7. What are important factors affecting on your design of classroom activities and tasks for your class?
8. Did you concern about classroom activities and tasks promoting students' CT? How did you do about such concerns?
9. Do you think which factors impact on your decide to design and implement activities and tasks relevant to CT?
10. What teaching methods or techniques are helpful to promote students' CT in chemistry?
11. In real teaching, how do you conduct your classes, in particular? What is a major classroom activity?
12. Do you think how much your teaching promotes students' CT? How? Give an example?
13. Do you think will you be able to integrate teaching for CT into your chemistry classroom? How should you do?
14. How do you assess your students' learning in chemistry?

15. What is your major goal in assessment students' learning?
16. Do you assess students in CT or thinking abilities within chemistry? How?
17. What factors, in your real teaching, support or hinder you to employ activities and tasks to promote students' CT?
18. What are your expectations to gain from participation in this PD program?
19. Do you have any suggestions or ideas relevant to teaching for CT in chemistry?

Semi-Structured Interview with Teacher Protocol (Final interview)

Teachers' Understanding about Teaching for Critical Thinking and Their own Development in Teaching for Critical Thinking

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Teacher: ____________________________ School: __________________________

Date: _______________________________ Time: ____________________________

Interviewer: ____

Interview Context: ____

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1. What are teaching for CT?
2. Do you integrate teaching CT into your teaching Chemistry?
   - If yes, how do you integrate it? Give me some examples of your actual teaching?
   - If no, why?
3. What are your goals of teaching Chemistry? (To develop students in CT?)
4. What teaching and learning Chemistry activities used by yourself challenge your students to think critically?
5. What could you observe students' behaviors in learning Chemistry?
6. Have some changes from your students' learning and thinking abilities? Give examples based on your actual classroom situations?
7. Do you have some changes in teaching practices through this academic year?
8. How does the participation in the PD program benefit you?
9. What points do you think that you are changing in teaching practices during this PD program?
10. What are features of the PD program support/hinder your development in teaching for CT? Why?
11. What are important factors affecting your learning in teaching for CT based on the context of the research study?
12. You do have any suggestions to professional developers in order to enhance in-service teachers in further thesis?

Semi-Structured Interview with Teacher Protocol

Post-Class Interview based on Classroom Observations

Teacher: ___________________________ School: _________________________

Date: ______________________________ Time: ___________________________

Interviewer: ____

Interview Context: ____

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1. What are your goals of teaching in this lesson?
2. What do you prepare to teach in this lesson?
3. Do students meet with such goals? What are you observed to support your answers?
4. How do you think about this lesson? Which point is the successful or unsuccessful lesson?
5. Does this lesson challenge your students to learning and thinking critically?
   If yes, how this lesson promotes students to think critically?
   If no, why does this lesson not promote students to think critically? And how this lesson should be changed to promote students' CT?
6. Which parts of this lesson seem mostly to promote students to think critically?
7. What are your teaching techniques in this lesson to motivate students' interaction and expressing their thought?
8. Are there any changes in students' learning behaviors observed in this lesson comparing previous lessons? (Give examples?)
9. Are there any evidences in this lesson to imply that your students were engaging in critical thinking activities? (Give examples?)
10. What factors facilitate or hinder your accomplishment in teaching lesson?

Semi-Structured Interview with Student Protocol (Phase II)

Students' Attitudes to Learning Chemistry and Teachers' Teaching

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Student: ____________________________ School: __________________________

Date: _______________________________ Time: ____________________________

Interviewer: ____

Interview Context: ____

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1. Could you please introduce yourself in brief?
2. What are your expectations in learning Chemistry?
3. What was your Chemistry grade in last semester?
4. What is your most favorite science subject (Biology, Chemistry, and Physics)? Why?
5. How much you love to study Chemistry, and why?
6. What parts or concepts of Chemistry are easy and difficult to learn? Why?
7. Which activities should be employed in Chemistry classroom and promote you great learning and thinking?
8. How does your gained knowledge from studying chemistry benefit you?
9. What are teaching methods used frequently by your Chemistry teachers?
10. Give me an example of Chemistry learning activity provided by the teacher that you like most? Why?
11. Are there any changes of your chemistry teacher teaching throughout this academic year? (Give examples)
12. What should be changed or remained in your chemistry teacher teaching?

Appendix B

Reflective Journals

Reflective Journal Protocol

Written Reflection of Teachers' Learning about Teaching for CT

Based on Classroom Practice

Teacher: ____________________________ School: ___________________________

Teaching Date: ______________________ Time: _____________________________

Teaching Concept: ____

Explanation: Please write or type a reflection based upon your teaching classrooms in this lesson

1. After teaching, Please write what you learned from your classroom teaching in the context of teaching for critical thinking and give some examples relevant to classroom situation:

    1.1 Introduce your classroom activities in brief (including: teaching concepts, teaching methods, tasks given to students, and learning assessment)

    1.2. What did you perform in the class that facilitates students in meaningful learning?

    1.3 What did you perform in the class that obstructs students' learning?

    1.3 Which parts of the class encourage students to think critically?

    1.4 What should be remained and changed in order to promote students' CT for a following lesson?

    1.5. What key factors facilitate your teaching lesson in the context of teaching for CT?

    1.6 What key factors hinder your teaching lesson in the context of teaching for CT?

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2. Suggestion related to professional development learning in teaching for CT

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Reflective Journal Protocol

Written Reflection of Teachers' Learning about Teaching for CT

Based upon the PD Program

Teacher: ____________________________ School: __________________________

Date: _______________________________ Time: ____________________________

<u>Explanation</u>: Please write or type a reflection based upon your participation in the PD program

1. Please write or type a reflection based upon your participation in the PD program in areas of:
   - Understanding of teaching that promote students to think critically
   - What changes or improvements of your teaching incorporation during participation in the PD program (goals of teaching, teaching preparation, conducting effective classroom practices, learning assessment, and so on)
   - What features/professional learning activities of the PD program support your learning how to teach for CT
2. What successes you meet with in teaching for CT as a result of participation in the PD program?
3. What factors facilitate/hinder your learning how to teach for CT during participating in the PD program?
4. Recommendations regarding teacher development relevant to teaching for CT in Chemistry

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Appendix C

The Workshop on Teaching for Critical Thinking

Appendix Table C 1 Time Table of the Workshop on Teaching for Critical Thinking in Chemistry

Date \ Time	**09.00-10.00**	**10.00-11.00**	**11.00-12.00**	**12.00-13.00**	**13.00-14.00**	**14.00-15.00**	**15.00-16.00**
Oct 27, 2009	Sharing experience	Think aloud: How do students learn chemistry; Coffee break	Critical thinking	Lunch time	Teaching for critical thinking	Coffee break	Teaching for critical thinking (continued)
Oct 28, 2009	Watching and reflecting on the teacher teaching practices	Coffee break	Watching and reflecting on the teacher teaching practices (continued)	Lunch time	Designing chemistry lesson plan for CT	Coffee break	Designing chemistry lesson plan for CT
Nov 8, 2009	Developing the lesson plans	Coffee break	Developing the lesson plans (continued)	Lunch time			

BIOGRAPHICAL DATA

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