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THESIS

ENHANCING THE CHEMISTRY TEACHERS' TEACHING PRACTICES BASED ON THE CONSTRUCTIVIST APPROACH THROUGH COLLABORATIVE ACTION RESEARCH

PRANOM JAPIN

A Thesis Submitted in Partial Fulfillment of
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This interpretive case study research aims to examine 1) how the chemistry teachers perform their teaching practices before participation in the Collaborative Action Research (CAR) project, and 2) what is the influence of CAR project on the chemistry teachers teaching practices based on a constructivist approach. The research is divided into 2 phases: an exploratory phase (first semester of academic year 2008) and a Collaborative Action Research (CAR) Phase (second semester of academic year 2008). The participants of this study were three chemistry teachers teaching at different secondary public schools under the Bangkok Educational Service Area, Office 2. The study took place in the context of a Collaborative Action Research professional development experience consisting of three cycles of CAR. Each cycle consisted of group meetings, teachers' lesson planning, implementation of the lesson plans, and reflection on their practices. This interpretive case study drew upon classroom observation, semi-structured interviews, teachers' lesson plans and participant observation in CAR group meeting. The approach to analysis involved an inductive process to search for patterns and making themes which constituted the research findings.

The findings indicate that at the beginning, before their participation in the CAR group, the three chemistry teachers did not teach according to constructivist principles. The teachers were not aware of students' prior knowledge, and were primarily concerned with covering the content knowledge, and so emphasized teaching based on the textbook. They also practiced teaching through lectures and demonstrations, emphasized student assignments, rarely encouraged the use of scientific inquiry, did not promote cooperative learning, used several learning assessment methods which relied on the right answer to assess students' learning, and emphasized tests. In summary, they were acting as information provider, individual planners and assessors. The findings of the CAR phase indicate that even though teachers' changes in practice did not completely shift from traditional teaching, in terms of change and growth, the opportunities for collaboration and reflection in the CAR group enriched teachers and allowed them to construct their own understanding and effect a change in their practices. As a result, the teachers gradually changed their practice to be aware of the need to elicit student prior knowledge, and of allowing students to take more responsibility for their own learning through hands-on and minds-on activities. They incorporated cooperative learning into their classroom, using more continuous assessment, and played multiple roles to help the students in learning. Because the teachers demonstrated difficulties to adopt and adapt constructivist principles into practice due to their different background and context of teaching, the implication of this study suggests that consideration should be given to the diversity of teachers' background as central to the facilitation of such a collaborative enterprise. In addition, it is recommended that teachers should be supported to carry on the professional development through CAR to improve teaching and learning.

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Student's signature Thesis Advisor's signature

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Pranom Japin

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CHAPTER I

INTRODUCTION

Overview of the Chapter

The first chapter of this study describes the background and context of the study, the problem area of the study which is the basis for the research objectives and research questions. To understand the scope of this research study, the definition of terms and delimitation of the study are described. The last section of this chapter provides a summary of this chapter and a brief description or overview of the research study.

Background of the Study

The educational reform stems from the major Asian economic crisis of 1997 triggered by the floating of the baht (Thai currency) and exacerbated by the resulting climate of unemployment. The need to improve the quality of education and the level of human resources in order to successfully compete in the global market was further highlighted. As a consequence of the economic crisis, political reforms such as the Constitution of the Kingdom of Thailand B.E. 2540, which was enacted in 1997, proclaimed that education is a major tool for the development of the Thai people (Office of the Council of State, 2005). Subsequently the first education law, the National Education Act 1999, of the country was enacted in 1999 and laid down a concrete foundation to initiate the reform and provide the framework and guidelines for the provision and development of Thai education (Office of the National Education Commission [ONEC], 1999). It emphasizes lifelong learning with a balance of knowledge, skills and attitudes. The aim is for all learners to be able to adjust to world trends and events, and to develop desirable characteristics including virtue, competency, happiness, and self-reliance (ONEC, 1999).

Science is considered to be a global culture for knowledge-based societies. It is necessary for people to be equipped with sufficient knowledge of science and its

implications. As is emphasized and stated in the Constitution of the Kingdom of Thailand, the goal is to accelerate the application of science and technology for national development (Office of the Council of State, 2005). In order to further scientific literacy for Thais, science education in Thailand has been promoted an important role in educational reform since 1997.

As noted above, the National Education Act became the crucial law that provided the framework and guidelines for the provision and development of Thai education. The science curriculum framework also was developed by the Institute for the Promotion of Teaching Science and Technology [IPST], in line with the Act, especially with sections 22 and 23 (ONEC, 1999; Ministry of Education, 2001). According to the Act the teaching and learning of science should focus on having the students mostly doing their own learning and discovering by themselves. The IPST set the formulation of science teaching and learning in schools, and has the following aims for the learners: to understand the principles and theories of basic science, to understand the boundaries, limitations and nature of science, to acquire the skills to inquire into and explore science and technology, to develop the thinking and imaginative process, and the ability to solve problems, to acquire management and communication skills and the ability to make decisions, to be aware of the relationships between science, technology, people and the environment in terms of their influence and impact on each other, to utilize the knowledge of science and technology to advance society and daily life, and to have scientific minds imbued with morality, ethical sense and the values for using science and technology creatively (IPST, 2003).

The Thai science basic education curriculum is in line with the National Education Act. The learning approach is often interpreted as being a constructivist approach (Kaewdaeng, 1998; Atagi, 2002; IPST, 2003; Pillay, 2002). A constructivist perspective on learning refers to the understanding of the nature of human learning, with knowledge actively constructed by the learners and not just given to them, with knowledge achieved through authentic learning. In order to provide students with opportunities and activities to learn science in line with the educational reform, science teachers need to use teaching approaches associated with constructivist views of

teaching and learning, and shift their role from being a teacher-centered director towards a learner-centered facilitator of learning (Office of the Education Council [OEC], 2006; Dahsah and Faikhamta, 2008). However, the need to raise the quality of the teaching profession is also emphasized in the Act.

Significance of the Study

As noted earlier, teachers are key players in educational reform, and teacher quality is the most significant determinant of school quality and school improvement (Hargreaves and Fullan, 1992; ONEC, 1999; Atagi, 2002). The National Education Act 1999 attaches great importance to the improvement of the quality of teachers and the raising of the status of the teaching profession. Among the changes required in the 1999 National Education Act, there were those expected from teachers in their teaching, learning and professional practices. With regard to the reform issues prescribed in the Act and geared towards the reform of teachers and the teaching profession, it is significant that they gave major consideration to teachers, the change process of teaching and learning, and other related issues.

In the current educational reform movement, the dominant thinking stresses many elements of the constructivist approach (Kaewdaeng, 1998; ONEC, 1999; Atagi, 2002). The constructivist paradigm, which the National Education Act relied on, signifies a concerted effort to move away from the traditional approach which is authoritarian, teacher-centered and didactic. The new bottom-up approach to teaching contrasts strongly with the existing traditional approach which has been the common practice of Thai teachers. For teachers to develop the competencies necessary to implement teaching based on the constructivist approach, they need a clear understanding of the disciplinary knowledge in the new curriculum, new learning strategies, and the assessment and evaluation methods. Further work and development must be undertaken on continuing professional development work in order for teachers, administrators, and facilitators to develop their understanding and skills (Atagi, 2002; Fry, 2002; Pillay, 2002; Dahsah and Coll, 2007).

In an attempt to further the understanding and eventually the implementation of the newly prescribed teaching and learning processes, many agencies offered the working procedure as guidelines for schools in the reform process. Among these agencies were, for example, the IPST, the Ministry of Education, the Rajabhats Universities, and the faculties of education in the universities. A review of current professional development programs, especially for in-service science teachers, in Thailand reveals that they emphasize the training orientation as an authoritative top-down system in which knowledge is usually conveyed by an outside expert (Fry, 2002; Pillay, 2002; Yutakom and Chaiso, 2007). In general, the programs for professional development are short-term workshops, one way learning, and need of support after the programs are finished (Yutakom and Chaiso, 2007). One significant limitation of the current professional development programs is that the teachers are passive recipients of knowledge from the trainer, and their existing knowledge or beliefs are not considered by the trainers. Even though there are various programs for professional development, they are not very successful (Yutakom and Chaiso, 2007). One problem is that teachers still lack understanding about constructivist-based or learner-centered teaching approaches, and lack techniques for facilitating the development of higher-order thinking skills, and for using new technologies in their classrooms (Atagi, 2002; Fry, 2002; OEC, 2004, 2005; Dahsah, and Faikhamta, 2008). It would appear that this type of professional development is not sufficient to bring about the desired changes and consequently students' achievement, ability, and skills are still low and do not meet the desired goals of the educational reform (ONEC, 2001; OEC, 2002; Wongwanich and Wiratchai, 2005; Yutakom and Chaiso, 2007).

In an attempt to facilitate the newly prescribed teaching and learning process, the essential components as guidelines for developing in-service science teachers in the reform process are offered. Firstly teachers must be empowered to enable them to develop their own creative teaching models, ones that are appropriate for their context and situation (Fry, 2002; Pillay, 2002). The emphasis should be on the development of life-long teacher learning and the provision of long-term support to teachers and other staff involved in the educational reform (Fry, 2002; Pillay, 2002). It needs reform that should involve collaborative learning, teamwork and systematic joint responsibility,

and should encourage teacher educational institutions to learn together with the schools (Piya-Ajariya, 2002).

Based on the literature, collaborative action research is used in this study as an alternative way of professional development. This form of research brings together secondary chemistry teachers, researcher, and university educator to collaborate, with the common goal of improving and changing teachers' practice in line with constructivist teaching. As a collective group, the chemistry teachers work and relate together to share experiences on problems in their classrooms, discuss ideas to solve their problems and to improve student learning, and analyze outcomes of their teaching practice (Collin, 2004). It is a process that provides teachers with the authority to plan and pursue their study and use their findings to improve their own teaching practice (van Driel, Beijaard, and Verlo, 2001). In this context, teachers can see how multiple perspectives inevitably can lead to better professional decisions (Sagor, 1992). Teachers are empowered with the intellectual opportunities to inquire about the topics that are most significant and relevant to them (van Driel *et al.*, 2001; Collin, 2004).

Central to collaborative action research in this study are teachers' contributions to the constructivist based teaching and learning approach. This entails a series of activities in collaborative action research in which teachers learn together and pursues their own research aiming to improve teaching and learning activities in their own classrooms. Then, action research can be embedded in teachers' practice, and can play an important role in teacher education and the reform of science education.

Purpose of the Study

The purpose of this study is to explore how chemistry teachers take action in their own educational situations to change their teaching in order to encourage students to construct a deeper understanding of chemistry concepts. The teachers join together in a collaborative action research group to examine issues related to constructivist teaching and learning, as a way of coming to a better understanding of how chemistry can be taught to students in a new paradigm of learning in accordance with the

educational reform. This study will also examine how the teachers, as a group, gain new knowledge about constructivist teaching and learning and attempt to create ways to teach from this perspective in an already existing practice. This study examines how each teacher engages in systematic, self-critical inquiry their own practices, in the light of alternative approaches to teaching.

Research Questions

This study examines the enhancement of chemistry teachers' teaching practice based on the constructivist approach through collaborative action research. The research study aims to answer these following questions:

1. How do chemistry teachers perform their teaching practices before participation in the collaborative action research project?

2. What is the influence of a Collaborative Action Research project on the chemistry teachers' teaching practices based on a constructivist approach?

Methodological Framework of the Study

The study reported in this thesis is aimed at identifying how chemistry teachers perform their teaching practices before participation in the collaborative action research group, and whether or not they change their teaching practices as a result of their participation in a collaborative action research group. I view the educational setting, for example, people interaction, classrooms, and schools as a complex world. The chemistry teachers in this study are persons who construct their own understanding and interpret the meaning of the social world in order to change their teaching practices to the constructivist approach. An interpretive methodology is employed as a framework for this study. Interpretive research primarily employs an inductive research strategy to construct a holistic view with rich and thick description (Lincoln and Guba, 1985). I believe this methodology can provide me with an appropriate plan to conduct the research aiming to answer the researcher's questions. A variety of data collection

methods under an interpretive methodology such as observations, interviews, and reviewing of documents, can provide the complex and holistic view of what teachers know, how they practice their teaching, and the reasons behind their practices.

Research Method

The method used in this investigation is that of a case study. It was particularistic in that it was concerned with how certain chemistry teachers changed their practices in a particular setting, using collaborative action research as a method of inquiry. It was naturalistic in that it took place in naturalistic contexts, and the teachers were not manipulated. The chemistry teachers were the cases of the study. This study attempted to describe contexts and settings of teachers' practice changes. Multiple sources were then used to provide a holistic and in-depth collection of data. From the data gathered, inductive analysis data was used to develop categories and themes of teachers' changes in their practice as a result of participation in the collaborative action research group. The details of each data collection method and data analysis are discussed in the next section of this chapter.

Data Collection Methods

In order to understand the performance of in-service chemistry teachers in the classroom, multiple data sources have been used during the research process. These were: classroom observation, semi-structured interview, and teachers' lesson plans. In the second phase, the research sought to understand how the teachers changed and applied their new understanding about constructivist principles in their classroom during participation in this study. The CAR group, including three teachers, on science educator, and myself, was developed to work together. Throughout the process in the second phase, there were three cycles of the collaborative action research. The activities in each cycle consisted of one group meeting held at Kasetsart University, which occupied approximately 3 hours, teachers' formulating their lesson plans, one or two lesson plans for each cycle, one-to-one individual teacher meetings with me before teaching the topic, teachers' implementing their lesson plans, and teachers' reflections

after teaching. The cycle of action research began with a CAR group meeting in which the members shared their experiences about teaching based on constructivist principles, discussed problems of teaching, suggested ways to solve those problems, and helped each other to designed lesson plans in collaborative circumstances. After the group meeting the teachers adopted what they learned to design their lesson with the assistance of myself, and then the teachers implemented their lesson plan in their classroom. After having finished teaching each lesson, they reflected on their teaching. The recurring cycle occurred when the teachers contributed their experiences to the CAR group, with the members learning from each other when they reflected on what had happened in the classroom and revised the next lesson plan accordingly. The data collection came from multiple data sources: participation in group meetings, classroom observation, semi-structured interview and teachers' lessons.

Data Analysis

The approach to analysis used here involved an inductive process: a search for correspondences and patterns and themes. Within-case analysis was made prior to cross-case analysis.

Definition of Terms

Collaborative Action Research

Collaborative action research entails teachers and researchers joining together to examine what their current problems and needs are. I as facilitator will help those teachers who need it to search for the way to solve their problems. In this context, teachers, science and researcher come together to share problems, set common goals, create change, and accomplish shared goals with regards to teaching and student learning in chemistry based on the constructivist approach.

Constructivism

Constructivism is a theory about knowledge and learning. Knowledge, in the constructivist theory, is individually constructed, socially and culturally mediated, and therefore non-objective. Learning is viewed as a self-regulated process in which knowledge is constructed through interaction with the environment, and through individual reflection and discourse with others.

Constructivist Perspectives of Teaching and Learning

Constructivist perspectives of teaching and learning are approaches to teaching and learning which are consistent with cognitive constructivism and social constructivism. Constructivist teaching and learning activities emphasize that students need to be active and take responsibility in their own learning process. The important components of this approach to teaching and learning consist of eliciting students' prior knowledge, doing hands-on and minds-on activities, promoting social interaction through cooperative learning, using a variety of assessment methods for students' learning, and utilizing continuous assessment.

Constructivist Teacher

A constructivist teacher is a teacher who designs frameworks for learning that emphasizes making connections between prior knowledge and new understanding.

Chemistry Subject

The chemistry subject described here is in the science curricular strands: substance 3; properties of matter at upper secondary education level for science-stream students.

Delimitation of the Study

This research study aimed to improve the teaching and learning of chemistry at the upper secondary school level, so as to be consistent with learning reform in Thailand. It was conducted during the Thai academic year 2008. Participants of this study were selected by purposive sampling. The willing participants consisted of three chemistry teachers from three different secondary public schools under the Bangkok Educational Service Area, Office 2. All schools were implementing the National Science Curriculum Standard. The scope of this study concerned the chemistry current teaching in upper secondary school and the change in chemistry teaching. This research aimed to examine and enhance chemistry teaching in line with the constructivist approach through collaborative action research.

Summary

Chapter 2 reviews the literature on: (i) Thailand education; (ii) teachers' professional development in Thailand; (iii) action research; and (iv) constructivism. Those topics are discussed to clarify the theory underpinning the research study. Chapter 3 outlines the research methodology, which consists of: (i) introduction; (ii) methodological paradigm and interpretive research; (iii) research design associated with a qualitative research approach; and, (iv) research design for this study. Chapter 4 presents the findings of the first phase of examining chemistry teachers' teaching practices from three case studies in their own classes. Then a cross case analysis among those three case studies is presented. Chapter 5 presents the findings of the teachers' changes in their teaching practices as a result of their participation in a collaborative action research group. Finally, Chapter 6 presents conclusion and implications which consists of: (i) review of the research framework; (ii) conclusions of the study; (iii) implications of the study; and (iv) suggestions for further study.

CHAPTER II

LITERATURE REVIEW

Overview of the Chapter

The first and second sections of this chapter comprise a literature review of Thailand educational reform and science education, and of the need for professional development in Thailand. In the third section, dimensions of action research and collaborative action research are reviewed. The fourth section is a review of constructivism. It begins with cognitive constructivism and social constructivism, followed by a discussion of literature about constructivism as a reference for science teaching and learning as well as a way for professional development. The objective here is to discuss the purpose of the constructivist approach and its impact on science teacher professional development and student learning. The components of the constructivist approach are discussed and used to guide the researcher towards a definition and application of the constructivist approach for the Thai educational context. The ways for professional development through collaborative action research are reviewed. This review aims to analyze strategies and characteristics of collaborative action research used in teacher development in order to promote in- service teachers' teaching practices based on the constructivist approach.

Thailand Education

Educational Reform

The need for educational reform in Thailand, which came to fruition in 1999 in the form of the National Education Act 1999, can be explained in both international and national contexts. Before the current educational reform, Thailand had undergone a rapid transformation from a predominantly agriculture-based, government-subsidized economy to an industrial, market-driven economy (Pillay, 2002). In industrial societies, manufacturing is the major industry and mass production at an acceptable level of

quality and at a reasonable cost drives industrial production. The skills demanded of the mass labor forces are generally limited to conducting tasks such as following manuals and assembling parts (Atagi, 2002). In 1997, there was a major Asian economic crisis triggered by the floating of the baht (Thai currency) and in the resulting climate of unemployment, the need to improve the quality of education and the level of human resources in order to successfully compete in the global market was further highlighted. Later analysis of this crisis led to the conclusion that there were major insufficiencies in many areas of the country's economic development, especially in the areas of science and technology (ONEC, 2001).

Thailand's current educational reform initiatives stem from the shock of the Asian economic crisis, and subsequent political reforms such as the Constitution of the Kingdom of Thailand B.E. 2540, which was enacted in 1997, proclaimed that education is a major tool for the development of the Thai people, protecting ones rights, and establishing equality (Office of the Council of State, 2005). The 1997 Constitution of the Kingdom of Thailand also provides the fundamental national policy on education in Section 81, which includes a requirement for the enactment of a national education law; for the improvement of education in harmony with economic and social change; for the development of science and technology; for the instilling of proper awareness; and for the promotion local wisdom and national and culture (ONEC, 2003; Office of the Council of State, 2005). Subsequently the first education law, The National Education Act was enacted in 1999 and laid down a concrete foundation to initiate the reform, and provides the framework and guidelines for the provision and development of Thai education (ONEC, 1999). It emphasizes lifelong learning with a balance of knowledge, skills and attitudes. The aim is for all learners to be able to adjust to world trends and events, and to develop desirable characteristics including virtue, competency, happiness, and self-reliance (ONEC, 1999). The major components of the National Education Act include: 1) Ensuring basic education for all; 2) Reform of the education system; 3) Learning reform; 4) Reorganization of the administrative system; 5) Introducing a system of educational quality assurance; 6) Enhancing professionalism and the quality of the teaching profession; 7) Mobilization of resources and investment for education; and, 8) Information and communication technology [ICT] for

educational reform.. The educational guidelines, in Chapter 4 of this act, suggest that the objectives of learning, approaches to learning, curriculum, assessment and evaluation methods, instructional media, and learning resources all need to be reformed.

The 1999 National Education Act has provided the framework and guidelines for the educational reform of Thailand. Later, the Basic Education Core Curriculum was promulgated in 2001 and gave the framework to change the Thai education system, teaching, student learning, and community participation. In 2002, in accordance with the National Education Act, 12 years of free base education was made available to students through the country. The government later increased that number to 14 years to include two years of pre-primary education (OEC, 2006). The basic education curriculum has a 14 years with two years (pre-primary instruction), six years of primary (grades 1-6), 3 years of lower secondary (grades 7-9), and 3 years of upper of upper secondary education (grades 10-12). Schooling at grades 1-9 is now compulsory (OEC, 2006). The framework provides objective, curricular strands, standards for curriculums, body of knowledge and learning outcomes, and assessment and evaluation methods of teaching and learning by the end of 12 years, as well as by the end of each grade level for each subject group. The subject groups in the Basic Education Curriculum are grouped into eight subject areas: Thai language; Mathematics; Science; Social science, religion and culture; Health and physical education; Arts; Career and technology; and Foreign languages (Ministry of Education, 2002).

Science Education in Thailand

Since science is considered to be a global culture for the knowledge-based societies, it is necessary for people to be equipped with sufficient knowledge of science and its implications. The goal of scientific literacy for all is to enable people to understand nature and man-made technological products and to use scientific knowledge reasonably, creatively, responsibly and ethically. Scientific knowledge is also able to enhance Thais' capability in economic development, international competitiveness and happy coexistence in a global community. Under the 1997

Constitution the state is required to help Thais attain knowledge and morality; to issue laws relating to national education; to improve education so as to be attuned to economic and social change; to create and strengthen knowledge and inculcate sound awareness of politics and a democratic system of government under a constitutional monarch; to promote research in various disciplines; to accelerate the application of science and technology for national development; to promote the teaching profession; and to encourage the revival of the wisdom, art and culture of the nation. As emphasized and stated in The Constitution of the Kingdom of Thailand, the government's role in science is to facilitate the progress of science and technology for the development of the country. Because of the importance of developing scientific literacy for Thais, science education in Thailand has been awarded an important role in educational reform since 1997.

The science curriculum framework that was developed by the IPST was in line with the National Education Act, especially in section 22 and 23 (ONEC, 1999; Ministry of Education, 2001). The teaching and learning of science emphasizes that the students should be doing the most learning and discovering by themselves. The IPST which set the formulation of science teaching and learning in schools has the following aims for the learners: to understand the principles and theories of basic science; to understand the boundaries, limitations and nature of science; to have the skills necessary to inquire and explore science and technology; to develop the thinking and imaginative processes, the ability to solve problems and acquire management, communication skills and the ability to make decisions; to be aware of the relationships between science, technology, people and the environment in terms of influence and impact on each other; to utilize knowledge of science and technology to advance society and daily life; and to have scientific minds, morality, and ethical sense and values for using science and technology creatively (IPST, 2003).

As noted above, the Thai science basic education curriculum is in line with the Act. The science learning process needs to take into consideration the fact that learners are the most important element. In order to reform the learning process, it should promote and develop the importance of the learner-centered teaching process, allowing

learners to develop learning and thinking skills, and with consideration for individuals' interests, aptitudes, pace and potential (Atagi, 2002; Pillay, 2002). This means that a learner-centered learning approach should be emphasized in science classrooms. The learner-centered learning approach is often interpreted as being a constructivist approach (Kaewdaeng, 1998; Atagi, 2002; IPST, 2003; Pillay, 2002). A constructivist perspective on learning refers to the understanding of the nature of human learning, with knowledge actively constructed by the learner and not given to them, with knowledge achieved through authentic learning, and with the tasks positioned in the zone of proximal development. The constructivist paradigm, which the Act relied on, signifies a concerted effort to move away from the traditional approach which is authoritarian, teacher-centered and didactic towards a learner-centered facilitator of learning (OEC, 2006; Dahsah and Faikhamta, 2008).

In summary, science education in Thailand is part of educational reform which is aligned with the 1997 Constitution and the 1999 National Education Act. According to this framework, Thai students are intended to learn science as part of lifelong learning with a balance of knowledge, skills and attitudes, in order to achieve scientific literacy. Approaches to learning science, the use of instructional media and technology, and the assessment and evaluation of student learning, all should be based on constructivist views of learning and teaching. However, the need to raise the quality of the teaching profession is also emphasized in the National Education Act, the idea being that each of these objectives would support the other.

Teachers' Professional Development in Thailand

Rational for Teachers' Professional Development

As noted earlier, teachers are key players in educational reform, and teacher quality is the most significant determinant of school quality and school improvement (Hargreaves and Fullan, 1992; ONEC, 1999; Atagi, 2002). The 1999 National Education Act attaches great importance to the improvement of the quality of teachers and the raising of the status of the teaching profession. Proposing the view that teachers

are the most important agents in this reform process, particularly to bring out the desirable changes in learners as well as the learning process, great emphasis is placed on various policies that aim to bring about changes in the way teachers teach and learn. Among the changes required in the 1999 National Education Act, there were changes expected from teachers in their teaching, learning and professional practices. Listed below are the changes required by the new law on teachers' teaching, learning and professional practices.

1. Teachers are to be role models of learners (Sections 6 and 7).

2. Teachers are lifelong learners and work towards continuous development (Sections 6, 25 and 30).

3. Teachers must be capable of teaching all types of learners, regardless of their physical, mental, intellectual, emotional, social and other differences (Section 10).

4. Teachers must be capable of organizing education of all types; namely, formal, informal and non-formal (Section 15).

5. Teachers must organize the teaching and learning methods through the learner-centered approach (Section 22).

6. Teachers must organize the teaching and learning methods for the development of numerous skills such as social, scientific, technological, mathematical, humanistic, etc. (Section 23).

7. Teachers must organize the teaching and learning methods based on first-hand experiences and activities (Section 24).

8. Teachers must be capable of assessing learners' performance (Section 26).

With regard to the reform issues prescribed in the National Education Act and geared towards the reform of teachers and the teaching profession, it is important to take careful consideration of teachers, the change processes of teaching and learning, and other related issues.

As noted earlier, the constructivist paradigm, which the National Education Act relied on, signifies a concerted effort to move away from the traditional approach which is authoritarian, teacher-centered and didactic. The new bottom-up approach to teaching contrasts strongly with the existing traditional approach which has been the common practice of Thai teachers. In order to develop the competencies necessary to implement teaching based on the constructivist approach, teachers need a clear understanding of the disciplinary knowledge in the new curriculum, new learning strategies, and the new assessment and evaluation methods. Further work and development must be undertaken in on-going professional development work in order for teachers, administrators, and facilitators to develop their understanding and skills (Atagi, 2002; Fry, 2002; Pillay, 2002; Dahsah and Coll, 2007).

In an attempt to facilitate the understanding and eventually the adoption of the newly prescribed teaching and learning process, many agencies offered the working procedure as guidelines for involving in-service science teachers in the reform process.

Form of Professional Development

Workshop and Teacher Training

In order to satisfy the teacher development needs related to the educational reform of introducing new teaching and learning methods, the major in-service science teacher training in new teaching and learning approaches for classroom teachers was through the face-to-face workshop and training program. Many workshops have been conducted by or in collaboration with, for example, the IPST, the Ministry of Education, the staff at Rajabhat Universities or Teacher Colleges, and the faculties of education and science in the universities (Yutakom and Chaiso, 2007). The workshops

often take place out of school, so that teachers must leave their classroom and students. The predominant form of professional development is short-term training or a workshop and lasts for 2-3 days or a week, and single – session workshops. The training involves workshops, actual practice, using of multimedia, and creating documents and handouts which will be applied to real classroom situations (Yutakom and Chaiso, 2007). However, most of teacher workshops are more geared to fostering an awareness type of the content knowledge rather than the processes associated with new teaching and learning approaches and strategies to educate students to be scientific inquirer (Yutakom and Chaiso, 2007). Nowadays, this type of training achieves continuity by monitoring or evaluating the training program to meet the needs of teachers and to develop the training program (Yutakom and Chaiso, 2007). However due to the nature of teacher trainings, in many programs staff meetings are rare.

School-Based Training [SBT]

Considering that in-service teachers cannot be taken away from their classrooms, there is an urgent need to direct resources to developing and planning the delivery of in-service training. School-Based Training focuses on training at school and meeting the needs of teachers (Puntumasen, 2004). Puntumasen summarizes the principles of SBT: the training is a developmental process based on the real situations and actual needs of both the schools and the trainees, with the ultimate aim of enhancing the trainees' capacities in organizing the learning process and the students' capacities. The training takes place at school which is called School-Based or sometimes in the community or Community-Based with the school being responsible for the training project. The trainer or teachers who are learning reform leaders enhance the trainees' capacities. The essential requisites are faith and genuine recognition on the part of the trainees and participation on a voluntary basis. Both trainers and trainees take efforts in conceptualization, planning and carrying out line training together. The training involves authentic practice, and making available different teaching and learning methods, media and activities, which will be applied to real situations in their classroom. The training is repeated on a continuous basis and makes uses of a variety of methods, involving regular group meetings and individual consultations, with the a

view to collectively finding solutions to problems and enhancing the students' learning. It is an on-going process, benefiting from the evaluation outcomes which are used for improvement in the planning. The ultimate aims of training are raising the quality and standard of the teaching profession as well as the students' capacities.

Distance Learning

Considering that teachers cannot be easily taken away from the classroom and that they are often at schools in remote areas, alternative models of delivering training via satellite was launch in collaboration with the IPST, the Distance Learning Foundation and Educational Television [ETV]. The information about the new concepts and practices is delivered to two ways by ETV and via internet. However, professional development in this approach is not offered locally through the program but at state-organized, centrally located venues, which requires teachers to travel. As the result of the effectiveness of this program, most of teachers need to interact with mentors or experts continuously for assisting and monitoring (Yutakom and Chaiso, 2007). In addition, Wunpan (2007) has studied teachers' opinions about science-math programs on educational television station, and found that the program emphasized the teaching process in regard to ethics more than it did the academic aspect. The program promoted the thinking process more than the learners' skills. In regard to the benefits the teachers obtained from the program, it was found that teachers received guidelines for teaching and learning using mixed media rather than using it as an example or learning media in their teaching and learning activities. The program focused on knowledge of teaching and learning activities more than it did on the learners' needs.

A review of current professional development programs, especially for in-service science teachers, in Thailand reveals that the training orientations as authoritative top-down systems, in which knowledge is usually conveyed by an outside expert and the teachers are passive recipients of knowledge (Fry, 2002; Pillay, 2002; Yutakom and Chaiso, 2007). These kinds of programs have some limitations, and do not achieve their aims of effecting a change in teacher behavior (Yutakom and Chaiso, 2007). Even though there are various programs for professional development, the

science education yet does not succeed. One hindrance is that teachers lack understanding of constructivist-based or learner-centered teaching approaches, and lack techniques for facilitating the development of higher-order thinking skills, and for using new technologies in their classrooms (Atagi, 2002; Fry, 2002; OEC, 2004, 2005; Dahsah, and Faikhamta, 2008). It would appear that this type of professional development is not sufficient to bring about the desired changes and consequently students' achievement, ability, and skills are still low and do not meet the desired goals (ONEC, 2001; OEC, 2002; Wonvanich and Wiratchai, 2005; Yutakom and Chaiso, 2007).

Requirements for Professional Development

In an attempt to facilitate the newly prescribed teaching and learning process, the essential components as guidelines for involving in-service science teachers in the reform process are offered. Firstly teachers must be empowered so as to enable them to develop their own creative teaching models appropriate for their context and situation (Fry, 2002; Pillay, 2002). Secondly, the reform of professional development programs needs to be a collaborative learning process, using teamwork and systematic joint responsibility, continuity of activities, monitoring, follow-up and quality evaluation (Piya-Ajariya, 2002). Therefore, not only individual professional development but also a professional community plays important roles in educational reform. Development of professional communities can have an effective impact on school quality beyond individual contributions. Piya-Ajariya (2002) also provides recommendations on learning reform which promote collaborative action research to improve learning outcomes and encourage teacher education institutions to learn together with the schools. Thirdly, the emphasis should be on the development of life-long teacher learning and the provision of long-term support to teachers and other staffs involved in the educational reform (Fry, 2002; Pillay, 2002; Yutakom and Chaiso, 2007). The program should be based on teachers' needs that are consistent with the problems of science education in Thailand.

In summary, according to the Act, teachers are key players in educational reform and their quality is the most significant factor for school quality. However some teachers are not familiar with, and lack an understanding of, these teaching and learning perspectives and activities set out in the Act. Therefore, teacher professional development has an important role in enhancing teacher teaching in line with educational reform. Emphasizing the development of life-long teacher education for learning and working as a group in collaborative fashion, are recommended. The next session is devoted to the key issues related to supporting teacher development.

Key Issues to Support Teacher Development

Usually, for some reformers, professional development consists mainly of knowledge- and skills- based approaches imposed on teachers on a top-down basis by experts or trainers from outside their own schools (Hargreaves and Fullan, 1992). Such methods often fail to involve the teacher, and therefore run the risk of generating teacher resistance. Now there is more evidence linking quality professional development and teacher expertise with students' opportunity to learn. The knowledge base on professional development has grown and that makes for a key characteristic of effective professional development.

Voluntary and Relate to Individual Needs

Effective professional development is more likely to be successful when it is voluntary and relates to individual needs (Darling-Hammond and Sykes, 1999). Teachers should be given the opportunity to themselves identifying what they need to learn in the development of the learning experience (Darling-Hammond and Sykes, 1999).

Engagement

Engagement, in this case, will increase teachers' motivation and commitment to learn. The teachers act as adult learners in the learning approaches that they will use

with their students (Loucks-Horsley, Love, Stiles, Mundry, and Hewson, 2003). Opportunities in the identification of what teachers need to learn, provide ample time for in-depth investigations, collaborative work, reflection, and connect explicitly with teachers' other professional development experiences and activities, enhances their sense of efficacy and affirms their strengths (Loucks-Horsley *et al*., 2003). It increases the likelihood that what is learned will be meaningful and relevant to particular contexts and problems for teachers in real situations. Further, training teachers to train other teachers or asking teachers to support or coach their colleagues in the school, or even engaging teachers with staff members to share their work, give feedback, and mentor, can diminish or even override many of the effects of top-down instruction (Hargreaves and Fullan, 1992).

Support Continuously

Moreover, it is essential to follow up and provide continuous support including support from colleagues and other experts in learning communities that can provide necessary resources and an outside perspective to improve teacher practices (Darling-Hammond and Sykes, 1999; Loucks-Horsley *et al*., 2003).

All these might establish effective professional development and reduce the risk of teacher resistance. The next section is devoted to action research as an alternative professional development model for the professional development.

Action Research

Common Ideas of Action Research

Action research in education has often been seen as a way of involving teachers in changes which improve teaching practice. The term, action research, was first used in the 1940s by Kurt Lewin who worked in the development of a collective problem-solving cycle for improving life in organizations (Calhoun, 1994). Based on Lewin's work, the assumption is that if teachers work together on a common problem, clarifying

and negotiating ideas and concerns, they will be more likely to change their attitudes and practices, if research indicates such change is necessary (Oja and Smulyan, 1989). There are three general aims of action research: staff development, improved school practice, and the generation or elaboration of theories of teaching and learning (Oja and Smulyan, 1989). In staff development, action research is viewed as increasing teachers understanding of their own practice in the classroom and school, and in this manner increasing self-esteem and/or greater feelings of capability in solving problems and making decisions. To improve school practice, teachers gain new knowledge which helps them to solve immediate problems, to extend their general knowledge base as professionals, and also to become skilled at research which can be applied to their teaching or future concerns. The last aim is the generating and elaborating of theories of teaching and learning underlying teacher practice. The theory can be grounded in the realities of the school and is generalizable to other educational contexts. In this perspective, action research is viewed as knowledge production.

Process of Action Research

Basically, the process of action research consists of a spiral of cycles of action and research with four major phases: plan, act, observe, and reflect (Kemmis, 1990; Zuber-Skerrit, 1990; Calhoun, 1994; Kemmis and Wilkinson 1998). The plan includes problem analysis and a strategic plan. Action refers to the implementation of the strategy planned. Observation includes an evaluation of the action by using appropriate methods and techniques. Reflection finally is done on the results of the evaluation and on the whole action research process. Critically, teachers are conducting action research on the careful collection of data to diagnose problems as well as a disciplined search for alternative solutions (planning), an agreement to act (acting), and the conscientious monitoring (observation) of whether and how much the solution worked, with a recycling of the process (reflection), and either attacking the problem again or focusing on another solution. Such processes are conducted for teacher development in which each teacher continually strives to improve their performance by learning to solve more and more problems. These activities aim at the improvement of practices, the

understandings of the practice by practitioners, and aim at the involvement of as many practitioners as possible of all activities.

Forms of Action Research

Action research in education and its related processes takes numerous forms. Generally, there are three main differences among the current approaches to action research, based on how many people are involved and whether the inquiry is conducted by individual teachers, by a small collaborative group, or by the entire school faculty (Calhoun, 1994). The individual teacher as researcher is usually focused on changes in a single classroom. On the other hand, collaborative action research depends on the number of teachers involved. Its focus might be on problems and changes in a single classroom, or on several classrooms within their schools. School-wide action research implies the improvement of everyone in the school who is involved in the inquiry. Each type has its virtues and its different purposes and results (Calhoun, 1994). In addition, to meet the combined goals of improved practice, expanded theory, and staff development, educational researchers could be involved in collaborative action research and examine the processes in which they are engaged, and use their findings to improve both the process and products of action research in the schools (Oja and Smulyan, 1989).

Collaborative Action Research

Collaboration

In education, action research has the potential to extend and enhance teachers' knowledge and can additionally result in personal growth through collaboration, authentic participation, power in their own work, and sharing the language used by the community (Collins, 2004). Collaboration is one of the key tenets of action research which allows for mutual understanding and consensus, democratic decision making, and common practice (Carr and Kemmis, 1986; Oja and Smulyan, 1989). Since teachers have to solve increasingly complex educational problems comfortably,

individually, teachers often confine themselves to the few teaching strategies they have found to be the easiest to use. The result is not widespread excellence in the classroom and nothing is improved in the time passed. Therefore, working with other teachers and educators in collaborative action research can help these teachers acquire more useful teaching strategies and better teaching skills (Sagor, 1992). Collaboration provides teachers with the support necessary based on teachers' interests or needs, and includes self-monitoring to make fundamental changes in their practices, changes that endure beyond the research process (Sagor, 1992; Oja and Smulyan, 1989). In addition, collaborative action research helps teachers to confront problems firsthand when the context of the interventions reported or discussed in the educational journals may or may not conform to the realities of research and practice (Sagor, 1992).

Common Problem

Collaboratively, the process is based on teams of practitioners who have common problems and work together to investigate issues related to the nature and context of the problem encountered (Oja and Smulyan, 1989; Sagor, 1992; Collins, 2004). Collaborative action research demands that research becomes practitioner-based and that all theorizing and practice taken place in the context of the classroom setting (Collins, 2004). Teachers have the opportunity to develop immediate and deeply relevant understandings of their situation, and learn to be involved actively in the process of dealing with those problems (Stringer, 2007). Collaborative action research entails teachers joining together to examine and take action in response to different issues and concerns related to their practices.

Share Power and Ownership

Common features of collaborative action research include control or ownership of the specific questions or problems teachers want to explore and the actions they carry out, in combination with group activities (van Driel *et al.*, 2001). However, collaboration also tries to share power through the democratic principles of shared understanding and shared decision making (Collin, 2004). While working with

teachers, researchers work toward improving teachers' own practices by facilitating organizational and operational processes, rather than defining and controlling teachers. In this approach, teacher-researchers come together to set and share common goals regarding teaching and student learning as well as for mutually establishing the research design. However, in the case of the implementation of an innovation, each individual teacher is stimulated to explore their own goal. They then solve problems in their practices. The data is collected, analyzed, and reported to the group members.

Focus on Practice

Throughout the research process, most collaborative action research focuses on immediate problems defined by practitioners who are participating in those researches (Oja and Smulyan, 1989; Collins, 2004). Teachers may come together to share insights and develop ideas and/ or they may use their findings primarily in their own classrooms context.

Teachers' Professional Growth

Another expected outcome of action research in education beyond the change in teachers' practice is teachers' professional growth. In addition, collaborative action research always proceeds through spiraling cycles, as suggested for example by Lewin in 1948 and Elliot in 1981 (Oja and Smulyan, 1989). Each provides a model of the process of action research which emphasizes recurring cycles of planning, acting, observing, reflecting, and revising or modifying the plan. The spiraling cycles are necessary to bring action research under the control of understanding that allows practitioners to use their own reflections, understanding, and developing theories to inform both practice and research (Oja and Smulyan, 1989). Teachers gain new knowledge which helps them solve immediate problems, broaden their general knowledge base as professionals, and learn research skills of how to analyze a problem, work with others to solve it, and evaluate their results (Oja and Smulyan, 1989).

Partnerships

Collaborative action research projects can be designed as a specific form of staff development in the context of the implementation of an innovation or current practice (Oja and Smulyan, 1989; van Driel *et al.*, 2001). Many articles and descriptions of collaborative action research often refer to the joint work engaged in by teachers or administrators working with university personnel, by intermediate service agency personnel, or by facilitators of an educational group (Feldman, 1996; Lynch, 1997; Parke and Coble, 1997; Bencze and Hodson, 1999; Capobianco, 2007). Throughout the research process, development and application allows both teachers and researchers to connect theory and practice with the opportunity for reflection, for unexpected insight into situational realities and for contributing their knowledge and skills (Oja and Smulyan, 1989; Feldman, 1996; Lynch, 1997; Parke and Coble, 1997; Bencze and Hodson, 1999; Capobianco, 2007). As a partnership, continuity is provided by the researchers through the communication and collaboration network they establish with those teachers or practitioners involved in the study.

Rationale for Using Collaborative Action Research

Collaborative action research is used in this study as way for chemistry teacher to identify, explore, and reflect upon the constructivist teaching approach. This form of research brings together secondary chemistry teachers, researchers, and university educators to collaborate, with the goal of improving and changing teachers' practice based on the constructivist approach. As a collective group, the chemistry teachers work and relate together to share experiences, discuss ideas, and analyze outcomes of their teaching practices. As a researcher, I myself, serve as the facilitator of the group, and guide and support the teachers in their inquiries. At each step of the study, each teacher identifies an issue or problem related to the constructivist teaching approach to be addressed. A group addresses members' concerns and then uses a recursive process of action research in carrying out the projects in classrooms.

The rationale for using collaborative action research is because systematically engaging in teacher research provides many opportunities for teachers, individually and collectively, to seek new routes for transforming and improving their own practice. It is a process that provides teachers with the authority to plan and pursue their study and to use their findings to improve their own teaching practice and/or student learning. It is a way of inviting teachers to find new ways of enhancing their practice. In other words, this form of teacher research heightens teacher efficacy.

Collaborative action research encourages teachers to share their search ideas, methods, data, and findings with others in an accustomed way in order to construct alternative viewpoints, perspectives, and approaches for practicing with groups of diverse students. In this context, teachers can see how multiple perspectives inevitably can lead to better profession decisions (Sagor, 1992).

In summary, based on the literature, collaborative action research is described as a process by which teachers gather together to engage in systematic, self-reflective inquiry of their practices for the purpose of improving as well as coming to a better understanding of that practice. By joining together, teachers find new ways to connect with one another in order to share and discuss their work. Central to collaborative action research in this study are teachers' contributions to the constructivist based teaching and learning approach. As researchers, teachers reflect, change, and modify their own practice. This entails a series of activities in which teachers use already existing knowledge and in effect, gain new knowledge by doing so.

Constructivism

Constructivism is a Theory of Learning

Constructivism has become a central epistemology in education and this has implications for science education. Constructivism is viewed as an epistemology or a theory about knowledge and learning (Fosnot, 1996). Constructivism is seen as a form of realism in the sense that the existence of a reality is recognized from the outset by

what is known about it in a personal and subjective way (Tobin and Tippins, 1993). A constructivist perspective acknowledges the existence of an external reality but realizes that we never know what that reality is actually like. The basis of constructivism can be described by looking at two major different approaches to the construction of learning: the cognitive constructivism and social constructivism.

The key idea that sets constructivism apart from other theories of cognition was launched by Jean Piaget (von Glasersfeld, 1995). Piaget's constructivist theory mentions that one cannot draw conclusions about the character of the real world from the viability of schemes of action. In his view, what we see, hear, and feel is the result of our own perceptual activities and therefore specific to our ways of perceiving and conceiving. Piaget's theory of knowing asserts that when a person encounters new experiences and events, the person seeks to assimilate those events and convert them to fit their existing mental structures (schema) or to revise the existing mental structures (schema) to accommodate the new information (von Glasersfeld, 1995). The mental structures, or schemas which Piaget defined as the mental representation of an associated set of perceptions, ideas, and actions, are formed and reformed based on experiences, beliefs, values, socio-cultural histories, and prior perceptions.

Based on Piagets' work, Ernst von Glasersfeld theorized a second type of cognitive constructivism termed radical constructivism. Ernst von Glasersfeld has had great influence on the development of constructivist theory in mathematics and science education (Matthew, 1994). By radical constructivism, von Glasersfeld meant a theory of knowledge that knowledge does not reflect the reality of an object, but knowledge is constituted exclusively by our experience in an ordering and organization of a world (Matthew, 1994; von Glaserfeld, 1995). For the radical constructivism, knowledge is in the heads of persons and knowledge is constructed by what he or she knows on the basis of his or her own experience (von Glasersfeld, 1995). Briefly, according to von Glaserfeld, one perspective on the process of knowledge construction is that the learner is the constructor of knowledge through the personal interplay of experience with their knowledge scheme and social activity of those experiences. The emphasis in learning is not on the correspondence with an external authority, but the construction by the

learner of schemes that are reasoned and useful to them. This view of knowledge has serious consequences for the conceptualization of teaching and learning that shift emphasis from the student's replication of what the teacher does correctly to the student's organization of their own experiences.

However, we cannot understand an individual's cognitive structure without observing it interacting in a context, within a culture. Some educators argue against the cognitive theory of Piaget and the radical constructivism of von Glasersfeld (Tobin and Tippins, 1993; Hardy and Taylor, 1997; Matthews, 1997). These educators argue that personal constructivism is flawed and problematic because it denies the socially and historically situated nature of knowing (Tobin and Tippins, 1993). Learning for these educators is dialectic between the individual and society, and thus there is an effect of social interaction, language, and cultural influence on learning.

Another view of constructivist theory is social constructivism derived primarily from the Russian psychologist, philosopher, and lawyer, Lev Vygotsky (Vygostky, 1978). Vygotsky is interested in the influence of culture on an individuals' learning. He argued that all cognitive functions originate in social interactions and that learning was not simply the assimilation and accommodation of new knowledge by the learner. Learning is the process by which learners are integrated into a knowledge community. Vygotsky believed that to understand human intellectual development and how humans perceive the world one must understand its social and historical circumstances.

Vygotsky (1978) advocated that children learn via activity and hence intellectual development should be the emphasis of the curriculum as teachers extend and challenge students to move their thinking from spontaneous to scientific concepts. Vygotsky (1978) uses the term zone of proximal development [ZPD] to describe the place where a child's spontaneous concepts meet the systematic logic of adult reasoning. The ZPD is the distance between the actual development level of the child as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygostsky, 1978). This zone varies from child to child and reflects

the ability of the learner to understand the logic of the scientific concept. Vygotsky also sought to study dialogue as the adult and the learners' converse, question, explain, and negotiate meaning. He argued that the most effective learning occurs when the adult draws the child out to the jointly constructed potential level of performance. Vygotsky believes that the cooperative relationship between the teacher and child is all important, due to the complex interaction between instruction and internal learning.

Vygotsky believed that when a student is at the ZPD for a particular task, providing the appropriate assistance will give the student enough of support to achieve the task. Vygotsky (1978) theorized that learning is a social and collaborative process and that knowledge is not simply constructed. The community surrounding the learner plays an important role as the learner constructs meaning from his/her surroundings. The collaborative learning methods are required as processes of students' interaction and the student is the main figure in the learning collaboration. According to Vygotsky, teachers use the possibilities of the social environment to direct and guide the student's activity, with the intent of encouraging further development through internalization.

As above, constructivist theory views the learner as an active agent of learning rather than as a passive learner who receives knowledge in the world. While cognitive constructivism is aligned with an emphasis on individual cognitive development, social constructivism emphasizes education for social transformation. However, in both views, there is an interaction between the learner and the environment. From this interaction, the learner constructs their own meanings. In response to new understandings from science and technology many educators have involved the concept based on the findings of cognitive and social constructivism on the theory and practice of science education (Matthew, 1994; von Glaserfeld, 1995).

Constructivism as a Reference for Science Teaching and Learning

Constructivism, as a set of beliefs about knowing and knowledge, can be used as a referent to represent a method of teaching, of analyzing learning potential, or even

as tool of critical reflection of student and teacher roles. The teacher bases what happens on beliefs of how to build a classroom that maximizes student learning. In addition, a constructivist perspective helps educators to decide what might comprise a curriculum.

The Importance of Prior Knowledge

Constructivists generally regard the purpose of education as educating the individual student in a fashion that supports their interests and needs. Individual cognitive development is the main emphasis. Learning is primarily an individualistic enterprise. Constructivist methods emphasize the engagement of the student in the learning process and the importance of prior knowledge or conceptualizations for new learning (Matthew, 1994). Work in this field reveals that when students begin science lessons, they already have knowledge schemes which they draw on in a learning situation (Driver and Bell, 1986). What students learn from lesson activities depends on both the nature of the tasks set and on the knowledge schemes that students bring to these tasks. Regarding the importance of student's knowledge schemes, Driver and Bell (1986) state that learning science is more than the taking in of new information; it is also a restructuring of the concepts or frameworks the learners already have. Learning thus involves an interaction between students' mental schemes and the experiences they have, and thus students construct their own new understandings or knowledge through the interaction between what they already know and activities with which they come into contact (Cannella and Reiff, 1994). The experience may fit in with students' expectations, in which case little change is required in the students' schemes. On the other hand, the experience may be new and students may change or adapt their knowledge schemes as a result. The process of using and testing current ideas in new situations requires the active involvement of students in drawing on their present schemes, relating them to new tasks, and perhaps reorganizing them. In this way, learning in science as well is seen to entail the progressive development and restructuring of learners' knowledge schemes.

Constructivism presupposes that all knowledge is acquired in relation to the prior knowledge that the students bring their prior knowledge to learning situations. The educator or teacher does have a mechanism for eliciting the prior knowledge of the students that need to be altered or modified by a teacher in order to present the new knowledge in a way that can be incorporated into the learner's construction of knowledge (Vadeboncoeur, 1997; Baviskar, Hartle, and Whitney, 2009). The teacher could facilitate this alteration by devising tasks and questions that create dilemmas for students (Vadeboncoeur, 1997). Driver and Bell (1986) describe constructivist teaching as being characterized by a number of steps, one of which is to elicit student's prior knowledge; this can be achieved by a variety of activities, such as group discussion, designing posters or writing. Richardson (1997) identifies characteristic instructional practices including hands-on activities, such as student tasks that challenge existing concepts and thinking processes; and questioning techniques that probe students' beliefs and encourage examination and testing of those beliefs. Windschitl (2002) also identifies some guidelines when planning a lesson in the constructivist classroom: (a) teachers must be aware of the student's prior awareness of ideas, (b) teachers need a clearly defined conceptual goal, (c) they need to include teaching strategies that challenge initial ideas, (d) the lesson plans need to offer opportunities to utilize new ideas, and (e) the teacher needs to create a classroom environment which encourages students to put forth and discuss ideas.

In summary, according to constructivism, all knowledge is acquired in relation to the prior knowledge that students bring to the classroom. The teacher must have a strategy for eliciting the prior knowledge of the students in order to present the new knowledge in a way that can be incorporated into the learner's construct.

Learning as an Active Process

Most science educators have supported the idea that constructivist learning is more focused on students than teachers (Yager, 1991). Learners are not viewed as passive but are seen as having purposive responsibility for their own learning (Driver and Leach, 1993). In constructivist views, learning involves the process of students

constructing their own meaning as an active process, one that often takes place through interpersonal negotiation (Driver and Bell, 1986; Driver and Leach, 1993; Matthew, 1994). The construction of meaning is a continuous and active process. Therefore, learners have the final responsibility for their learning. There are patterns in the types of meanings students construct due to shared experiences with the physical world and through natural language. One of the learning models proposed by Yager (1991) is the Constructivist Learning Model [CLM] which supports an active learning process led by learners. Students acquire personal knowledge through their interactions within their communities. Yager's Constructivist Learning Model (Yager, 1991) illustrates the essential strategies. They include:

1. Seeking out and using student questions and ideas to guide lessons and whole instructional units.

2. Accepting and encouraging student initiation of ideas.

3. Promoting student leadership, collaboration, location of information, and initiative as a result of the learning process.

4. Using student ideas, experiences, and interests to drive lessons (this means frequently altering teachers' plans).

5. Encouraging the use of alternative sources for information both from written materials and experts.

6. Using open-ended questions and encouraging students to elaborate on their questions and their responses.

7. Encouraging students to test their own ideas, i.e., answering their questions, their guesses as to causes, and their predictions of certain consequences.

8. Seeking out student ideas before presenting the teacher's ideas or before studying ideas from textbooks or other sources.

9. Encouraging students to challenge each other's conceptualizations and ideas.

10. Using cooperative learning strategies that emphasize collaboration, respect of individuality, and use of division of labor tactics.

11. Encouraging adequate time for reflection and analysis, and respecting and using all ideas that students generate.

12. Encouraging self-analysis, the collection of real evidence to support ideas, and the reformulation of ideas in the light of new experiences and evidence.

According to Brooks and Brooks (1993), educational settings that encourage the active construction of meaning have several characteristics:

1. They free students from the dreariness of fact-driven curriculums and allow them to focus on large ideas.

2. They place in students' hands the exhilarating power to follow trails of interest, to make connections, to reformulate ideas, and to reach unique conclusions.

Saunders (1992) also suggested some points as effective teaching strategies which can be used to implement constructivist perspectives in science classrooms. His idea is based on the principle that sensory experiences and active learning help learners' generate meaningful understandings. In order to resolve students' cognitive dis-equilibration, hands-on laboratory activities based on the investigative or inquiry approach are effective. And to enhance meaningful learning, the classroom activities can provide active cognitive involvement by providing a cognitive conflict to students.

In summary, the construction of understanding is a continuous and active process, in which learners have the final responsibility for their learning. To enhance meaningful understanding, teachers should create educational settings and use teaching strategies which can encourage the active construction of knowledge in their science classrooms.

Learning Science through Social Interaction

Learning science involves being initiated into the culture of science which holds that scientific ideas and theories result from the social construction of scientific knowledge (Driver and Leach, 1993). There is an important point at issue for science education. In learning science, students need to be given access to the concepts of conventional science. An individual's ideas should be affirmed and shared by others in classroom exchanges that have a part in shaping the knowledge construction process.

Regarding the social dimension in learning and the construction of knowledge, small-group work based on investigations is effective in stimulating students' higher level thinking activities. Using group work as a basis for the social organization of the classroom gives students opportunities to think through and exchange ideas with their peers (Driver and Leach, 1993). Windschitl (2002) mentions that in learning with a social dimension, students are given frequent opportunities to engage in complex, meaningful, problem-based activities. Students work collaboratively in cooperative learning activities and are given support to engage in task-oriented dialogue with one another, both with their peers and teachers, to co-construct meaning.

Many educators have introduced group process to classrooms that are common in cooperative learning. Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each other's learning. Students work through the assignment until all group members successfully understand and complete it. The essential components of cooperation are positive interdependence, face-to-face promotive interaction, individual and group accountability, interpersonal and small group skills, and group processing (Johnson, Johnson, and Holubec, 1993).

Systematically structuring of those basic elements into group learning situations helps teachers to ensure cooperative efforts and they enable the implementation of cooperative learning for long-term success.

The widespread use of cooperative learning is visible in the variety of cooperative learning methods available ranging from very concrete and prescribed to very conceptual and flexible. Almost many teachers can find a way to use cooperative learning that is congruent with his or her philosophies and practices. So many teachers use cooperative learning in so many different ways, as for example, Group Investigation [GI] (Sharan and Sharan, 1990), Jigsaw (Aronson, Stephen, Lides, Blaney, and Snapp, 1978), Teams-Games-Tournaments [TGT] (Slavin, 1990), and Student Teams Achievement Divisions [STAD] (Slavin, 1978).

In summary, as mentioned above, the construction of scientific knowledge has resulted in the scientific community sharing a view of the world. Learning science also involves being initiated into the culture of science. An individual's ideas should be affirmed and shared by others in classroom exchanges, an activity that has a part in shaping the knowledge construction process. In classroom practice, teachers should practice and rely heavily on collaboration among students. The main reason this approach is used so much in constructivism is that students learn about learning not only from themselves, but also from their peers. When students review and reflect on their learning processes together, they can pick up strategies and methods from one another.

Assessment as a Part of the Learning Process

As regards a way of assessing the true potential of students, the constructivists emphasize continuous learning assessment rather than viewing assessment as a process carried out by one person, such as a teacher in a more traditional, direct instruction approach in which students would be given written tests after a certain amount of material had been covered. In the constructivist classroom, assessments are made daily, and within the context of the inquiry (Gregory, 2002). In the constructivist classroom,

assessments are made continuously and are seen as inextricably linked and not separate processes (Holt and Willard-Holt 2000; Gregory, 2002). Assessments are seen as formative, prompting students to rethink and inquire further (Gregory, 2002). Windschitl, (2002) suggests that teachers could employ a variety of assessment strategies such as the observation of learning behaviors and participation in activities, self-evaluation, and tests, in order to understand how students' ideas are evolving and to give feedback on the processes as well as the products of their thinking. The role of the teacher becomes one of entering into conversation with the students being assessed to find out their current level of understanding on any task and sharing with them possible ways in which their understanding might be improved or their newly constructed knowledge refined. One key component to constructivist thinking is that the teachers share responsibility on their own assessment authority with their students as self-assessors (Jonassen, 1992; Gregory, 2002).

In summary, assessments in constructivist environments are more concerned with assessing the knowledge construction process within a variety of contexts and not as much concerned with assessing knowledge. It is no a separate step coming at the end of the learning process but a part of the learning process. There is not one correct understanding and there is no one method to assess students' understanding. A variety of assessment methods are employed to document the learners' growth and to look for changes in their thinking and learning skills and to indicate the quality of the learning experience, all of which serves as a direct foundation for further development.

Multiple Roles of the Constructivist Teacher

A teacher plays an important role in providing an engaging teaching and learning environment. This shift in a teacher's roles and responsibilities from that of a dominant information feeder to a facilitator is seen as most important in a constructivist context (Richards, 1998; Witfelt, 2000; Windschitl, 2002). The teacher is a mediator between students and their environments, and not simply a giver of information and manager of behavior. Witfelt (2000) listed new teacher competencies in constructivist contexts that include: supervisor, supporter and facilitator of students' work, advisor

and subject-matter expert, inspirer and encourager, arbiter at group discussions, critic in mobilizing greater effort when objectives are not being met, and evaluator to improve general learning capacities of students. Brooks and Brooks (1993) describe the duties of constructivist teachers: to encourage and accept student autonomy and initiative, to use raw data and primary sources, along with manipulative, interactive, and physical materials, to allow student responses to drive lessons, shift instructional strategies, and alter content, to inquire about students' understandings of concepts before sharing their own understandings of those concepts, to encourage students to engage in dialogue, both with the teachers and with one another, to encourage student inquiry by asking thoughtful, open-ended questions and encouraging students to ask questions of each other, to seek elaboration of students' initial responses, to engage students in experiences that might engender contradictions to their initial hypotheses and then encourage discussion, to allow wait time after posing questions, to provide time for students to construct relationships and create metaphors, and to nurture students' natural curiosity through frequent use of the learning cycle model. Baviskar *et al*. (2009) identify the constructivist teacher's roles as creating a context where the learner is motivated to learn. The roles of teacher include providing content, information resources and the tools necessary to mediate learning, posing relevant problems and questions, linking these resources and questions to the students' prior knowledge, helping students elaborate on or restructure their current knowledge, and assisting students to construct their own meaningful understanding. Driver and Leach (1993) identifies the teacher's role in the constructivist classroom as that of becoming a facilitator or guide, or as being the more diagnostic one of listening to students in order to understand their thinking and then intervening, when appropriate, with suggested ideas or experience to extend students' thinking, and thereby ensuring that the classroom environment is a supportive one where learners feel able to contribute their ideas.

As noted above, within a constructivist classroom, the teacher plays multiple roles that enable the students to find and make their own connections, so as to result in valid internalized meanings unique to the students. The teacher does this by asking questions to see how students may have previously constructed information related to

the topic. The teacher provides an environment for understanding the social and collaborative nature of learning. The teacher leads the students through exploratory activities that enable them to investigate on their own and come to their own conclusions as to what is happening. The teacher guides students by asking questions that will lead them to develop their own conclusions on the subject. The teacher interacts with each student to see how they are constructing the new information and helps them formulate sound conclusions by aiding the students in reconstructing the information in ways that are both valid and meaningful to them.

The Constructivist View on Professional Development

On view of adult learning, the principles of constructivist theory are adopted for professional development such as collaborative action research which it advocates the importance of aiding and allowing teachers to build bridges in their own minds between that which is known and that which they are coming to know (Macpherson, Arcodia, Gorman, Sherphed, and Troust, 1998). Based on the group learning, Schön (1987 cited in Atay, 2006) believes that in questioning, discussing, and checking beliefs and practices with others, teachers make implicit knowledge explicit and progressively and improve control of their own teaching. Within this constructivist framework, teacher education programs for educational research should include opportunities for teachers to become aware of their own practices and teachers are encouraged to construct their knowledge to become active participants in research (Atay, 2006).

Summary

This chapter describes the review of the literature on the importance for science teacher professional development in the Thai educational context; action research, collaborative action research, and constructivist theory that can lead to the principles for developing professional programs and designing research methodology. In Chapter 3, the methodology of this thesis is discussed particularly with reference to collaborative action research projects, the qualitative research methods, the research methods using in this study, trustworthiness, data collection, and data analysis.

CHAPTER III

METHODOLOGY

Overview of the Chapter

In Chapter Two, constructivist views of learning and the conceptualization of action research were discussed. The discussion of these views provides a framework to understand how people learn, particularly how in-service teachers learn and develop in their teaching profession. The integration of constructivist views of learning is presented as a theoretical framework used to develop an activity to enhance in-service chemistry teachers' teaching practices based on constructivist principles. There are two research questions which are investigated in this study:

1. How do chemistry teachers perform their teaching practices before participation in the collaborative action research project?

2. What is the influence of a Collaborative Action Research project on the chemistry teachers' teaching practices based on a constructivist approach?

This chapter sets out the research methodology used to address the research questions. The research methodology is conceived to be a theoretical framework and the rationale assisting me to plan the inquiry process and select the choice of methods of both data collection and data analysis (Patton, 2002; Crotty, 2003). The first section outlines the methodological paradigm for the research, which includes the justification of why the interpretive methodology was chosen. The second section the research design associated with a qualitative research approach. The last section outlines the research design for this study, and includes the following: participants; role of CAR members; CAR program; data gathering methods; data analysis and interpretation; ethical considerations and trustworthiness of the study.

Methodological Paradigm and Interpretive Research

Qualitative research has become an increasingly important mode of inquiry for the social sciences and applied fields such as education (Marshall and Rossman, 2006). Qualitative research constitutes proper inquiry within the qualitative, or interpretive, paradigm, which presents a refinement of what the researcher thinks about the world (Lincoln and Guba, 1985; Marshall and Rossman, 2006). Under the interpretive paradigm, qualitative research is pragmatic, interpretive, and grounded in the lived experiences of people, and it draws upon multiple methods of inquiry (Marshall and Rossman, 2006). The research methodology is also derived from a paradigm which has a crucial role in the inquiry because it is the philosophical foundation underlying types of research (Lincoln and Guba, 1985). Research methodology is the strategy, plan of action, process or design lying behind the choice and use of particular methods, and links the choice and use of methods to the desired outcomes (Crotty, 2003). It is also an account of the rationale it provides for the choice of methods and the particular forms in which the methods are employed (Crotty, 2003)

Interpretive research is aimed at understanding the meaning people have constructed; that is, how they make sense of their world and the experience they have in the world. Under the interpretive paradigm, qualitative research is naturalistic in that the researchers do not attempt to manipulate or control the research setting because, in this view, the research setting is subject to change (Lincoln and Guba, 1985; Marshall and Rossman, 2006). The qualitative methodological paradigm draws on multiple methods, and interpretive researchers use themselves as a primary research instrument in both data collection and analysis, which the researcher needs to get close to data sources to interact with, respectively, the participants and understand participants and contexts to study (Merriam, 1998; Patton, 2002; Marshall and Rossman, 2006).

Qualitative research is fundamentally interpretive (Marshall and Rossman, 2006). Interpretive research primarily employs an inductive research strategy to understand a holistic view with rich and thick description (Lincoln and Guba, 1985). When the interpretive researchers collect data they gather multiple aspects of the setting

under study to gain a comprehensive and complete picture of a particular context. Typically, qualitative research findings are in the form of themes, categories, typologies, concepts, and tentative hypotheses, which have been inductively derived from the data to identify the multiple realities under the study setting to be found in those data collected (Lincoln and Guba, 1985).

The study reported in this thesis is aimed at identifying how chemistry teachers perform their teaching practices before participation in the collaborative action research group, and whether or not they change their teaching practices as an influence of their participation in a collaborative action research group. I view the educational setting, for example, peoples' interaction, classrooms, and schools, as a complex world. The chemistry teachers in this study are persons who construct their own understanding and interpret the meaning of their social world to change their teaching practice to that of the constructivist approach. An interpretive methodology is employed as a framework for this study because I believe this methodology can provide me with an appropriate plan to conduct the research aiming to answer the researcher's questions. A variety of data collection research methods under an interpretive methodology, such as observations, interviews, and reviewing of documents, can provide the complex and holistic view of what teachers know, how they practice, and the reasons for their practice. In the next section, the research methods used under the interpretive methodology, such as case study, observations, interviews, and review of documents, are discussed.

Research Design under Interpretive Research

Case Study

Definitions of Case Study

The qualitative case study can be defined in terms of the process of actually carrying out the investigation, the unit of analysis (the bounded system, the case) or the end product (Merriam, 1998). The case study aims at investigating complex social units

consisting of multiple variables of potential importance in gaining an in-depth understanding of a particular situation or bounded system such as an individual, program, event, group, intervention, or community (Merriam, 1998). This specificity of focus makes it an especially good design for the researchers who need to understand a unique situation, and face practical problems, situations, or puzzling occurrences arising from everyday practice (Merriam, 1998).

Another key feature of a case study is an intensive and holistic description (Merriam, 1998). Descriptive means that the end product of a case study is a rich, "thick" description, which means the complete, literal description of the incident or entity being, investigated (Merriam, 1998).

As mentioned above, a case study is generally studying a single case, and one cannot generalize from that case to other cases which usually have different features. To deal with this concern, multiple case studies and cross-case analysis are used. Multiple case studies involve collecting and analyzing data from several cases. Merriam (1998) argues that multiple case studies can give greater variation across the cases, and enhance the external validity or generalizability of the researcher's findings.

In this study, the method of study used is a case study. This study fulfilled the characteristics of case study design as discussed above. It was particularistic in that it was concerned with how chemistry teachers changed their practice in a particular setting, using collaborative action research as a method of inquiry. It was naturalistic in that it took place in naturalistic contexts and the teachers were not manipulated. The chemistry teachers were the cases of the study. This study attempted to describe contexts and settings of the teachers' changes in practice. Multiple sources were then used to provide a holistic and in-depth collection of data. From the data gathered, inductive analysis as the model for data analysis was used to develop categories and themes of teachers' changes in their practices as a result of participation in the collaborative action research group. The details of each data collection method and data analysis are discussed in the next section of this chapter.

Selection of Case

In conducting case study research, the selection of a case is important because a case study focuses on a few instances of particular phenomena with a view to providing an in-depth understanding and a holistic view of events, relationships, programs or processes taking place in particular instances. Purposive sampling is recommended in choosing what case to study, so as to gain rich information (Stake, 1995; Merriam, 1998).

In this study, the teachers who the researcher communicated with were interested and willing participants in this research study, and were selected by using purposive sampling. The teachers were chemistry teachers and were interested in teaching based on the constructivist approach and would have to make time outside school hour for this study. They were also selected as having easy access to Kasetsart University. This made traveling safe, comfortable, and convenient for them. After each teacher responded positively to the opportunity to participate in this study, I visited each school personally and met first with the head and then the invited teachers to once again orally explain the purpose and expectations of the research. The research procedure is discussed later in the research design section.

Strategies for Collecting Data

Observations

Observation is regarded as a fundamental and highly important method in all qualitative inquiry (Marshall and Rossman, 2006). Patton (2002) argues that observational data is purposely describe the physical setting, the activities that take place in that setting, the people who participate in those activities, and the meaning of what is observed from the perspectives of those observed. Observational technique is different from an interview because it offers a firsthand account of the situation under study, such as an activity, event, or situation. It is the technique of choice when

participants are not able or willing to discuss the topic under study (Merriam, 1998; Patton, 2002).

Before collecting information, researchers need to know the extent to which the observer will be a participant in the setting being studied (Glesne, 1999; Patton, 2002). There are several stances an investigator can assume when conducting observations, from being a member of the group and a complete participant – an insider- to being a complete observer, unknown to those being observed. Each stance has its advantages and drawbacks.

Observation does have an advantage in providing rich data of what happens in natural settings and people, but it also has limitations due to the possibility that the observer may affect the situation being observed in unknown ways, and this interaction may lead to a distortion of the situation as it exists under non-research conditions (Merriam, 1998). To deal with these concerns, Bell (1993) suggests that researchers should be aware of their roles, and observe and record data in a way that aligns with research purposes as much as possible. Observations are also limited in focusing only on external behaviors, for the observer cannot see what is happening in people's minds. Moreover, observational data are often constrained by the limited sample of activities actually observed. Researchers need other data sources to find out the extent to which observed activities are typical or atypical (Patton, 2002).

Interviews

The interview is a method of data collection aimed at understanding what is happening in people's minds. The main purpose of an interview is to obtain a special kind of information that the researcher wants to find out; that is, what is in and on someone else' mind (Patton, 2002). The interviewing is necessary when interviewers or researchers cannot observe behavior, feelings, or how people interpret the world around them (Merriam, 1998). When using the interview, the interviewer can motivate interviewees to discuss their interpretations of the world in which they live and express

how they regard situations from their points of view (Cohen, Manion, and Morrison, 2000).

Interviewing varies in terms of a prior structure and in the latitude the interviewee has in responding to questions (Marshall and Rossman, 2006). Patton (2002) categorizes qualitative interviews into three general types: the informal conversational interview, the general interview guide approach, and the standardized open-ended interview (Patton, 2002). The informal conversational interview relies entirely on the spontaneous generation of questions in the natural flow of an interaction. The informal conversational interview offers maximum flexibility to pursue information in whatever direction appears to be appropriate and which flows from the immediate context. The general interview guide involves outlining a set of issues that are to be explored with each respondent before interviewing begins. The standardized open-ended interview consists of a set of questions carefully worded and arranged with the intention of taking each respondent through the same sequence and asking each respondent the same questions with essentially the same words.

The decisions about what kind of interview techniques a researcher should select depend on the research purposes. Researchers need to be aware of the strengths and weaknesses of each technique. Interviewing has limitations and weaknesses. Interviews involve personal interaction; cooperation is essential (Marshall and Rossman, 2006). The emotional state of the interview, bias on the part of the interviewer, and the expertise of the interviewer may greatly affect the interview data (Bell, 1993; Cohen *et al*., 2000; Marshall and Rossman, 2006).

Review of Documents

Document review is another method of data gathering which can overcome the weaknesses and limitation of interviews and observations. Documents are a ready-made source of data easily accessible to the imaginative and resourceful investigator (Merriam, 1998). The term document is used as the umbrella term to cover a wide range of written, visual, and physical material related to the research (Bogdan and

Biklen, 1992; Bell, 1993; Merriam, 1998). The major types of documents can be described in three major categories, which include public records such as the statistical data base of the Center for Educational Statistics, personal document such as diaries, letters, scrapbooks and photo albums, and physical material such as utensils and instruments of everyday activity. The documents in a qualitative study of classroom instruction would be in the form of instructors' lesson plans, student assignments, official grade reports and school records, and so on (Merriam, 1998). The documents are reliable and stable sources of information and provide the researchers with information about many things that cannot be observed or have taken place before the research began (Merriam, 1998; Patton, 2002). The document data is available at all times which allow researchers to pick up document data from the past or present at the time of study. Many documents or artifacts cost little or nothing and are often easy to obtain. Finally, they are a product of the context of the problem being investigated (Merriam, 1998).

However, researchers should carefully choose their document data because there are a variety of document data which are not produced for research purposes, and the information they offer may not be in a form that is useful (Merriam, 1998). The researchers should be aware of which document contains information or insights relevant to the research questions (Lincoln and Guba, 1985; Merriam, 1998; Patton, 2002). Because the data contained in documents describe persons' actions, experiences, beliefs, attitudes, and views of the world, they are subjective data. Document data also can be challenged on the basis of their authenticity and accuracy. Researchers should determine as much as possible about the document, its origins, and reasons for being written, its author, and the context in which it was written (Bell, 1993; Merriam, 1998).

Data Analysis

Because raw data have no inherent meaning, data analysis is a process of bringing meaning to raw, inexpressive data for the reader or other researchers (Marshall and Rossman, 2006). The qualitative analysis lies in making sense of massive amounts of data which are transformed into findings (Patton, 2002). This involves reducing the

volume of raw information, sifting trivia from significance, identifying significant patterns or themes, and constructing a framework for communicating the essence of findings, a transformation for which no set formula exists (Patton, 2002; Marshall and Rossman, 2006;). In this qualitative research, the process of data collection and analysis is a simultaneous process of research which is recursive and dynamic (Merriam, 1998). For example, the researcher begins analysis with the first interview, the first observation, the first document read. Emerging insights and tentative hypotheses direct the next phase of data collection so as to achieve saturated information and a better understanding of that data, which in turn leads to the refinement or reformulation of questions. The process continues until the reformulation covers all cases studied (Robinson, 1951 cited in Merriam, 1998).

Qualitative research is particularly oriented toward exploration, discovery, and inductive logic. The methods of data analysis are generally based on an inductive process. Inductive analysis typically begins with building general patterns, categories, dimensions, and or theories as the researcher comes to understand patterns that exist in the phenomenon being investigated (Merriam, 1998; Patton, 2002). The strategy of inductive designs is seeking the multiple interrelationships among dimensions that emerge from patterns found in the cases under study, without presupposing in advance what the important dimensions will be. Inductive analysis is also used to test tentative explanations in ongoing data collection, in order to build on a solid foundation of specific, concrete, and detailed observations, quotations, documents, and cases.

In case study research, an inductive approach begins by constructing individual cases by bringing all the information about the case together and categorizing those cases (Merriam, 1998; Patton, 2002). A case study is an intensive, holistic description and analysis of a single, bounded unit aimed at conveying an understanding of the case (Merriam, 1998). Multiple or comparative case studies involve collecting and analyzing data from several cases. In a multiple case study, there are two stages of analysis: the within-case analysis and the cross-case analysis. For the within-case analysis, a single case is first treated and data are gathered so that the researcher can gain as comprehensive a view of the contextual variables as possible that might have a bearing

on the case. Once the analysis of each case is finished, cross-case analysis can begin. A qualitative, inductive, multi-case study seeks to build patterns and themes or a general explanation of processes and outcomes that occur across cases that fit each of the individual cases, even though the cases will vary in their details (Yin, 1994; Patton, 2002). The researchers then attempt to develop more sophisticated descriptions and more powerful explanations covering all cases (Miles and Huberman, 1994).

Strategies for Ensuring Trustworthiness of Data Collection and Analysis

In producing valid and reliable knowledge, trustworthiness of data collection and analysis are paramount. When a researcher wants to contribute results that are believable and trustworthy, he/she employs four different criteria in assessing the trustworthiness of qualitative research: credibility, transferability, dependability, and confirmability (Lincoln and Guba, 1985).

Credibility is a new term, replacing the term internal validity, to demonstrate the degree of confidence that the findings of the study are true for the subject of the study, and that there is compatibility between the researcher's constructions and the respondents' reality. Lincoln and Guba (1985) suggest strategies of research inquiry to ensure credibility. Their strategies are: prolonged engagement by having sufficient time in the field to understand daily events in the way that participants understand them; testing emerging assertions by evaluating their plausibility of emerging assertions against the data set; triangulation-checking by using source triangulation, analyst triangulation, theory triangulation; adequate reference materials-necessary to richly reconstruct the setting for the reader; peer debriefing by stepping outside the research setting to consult with other knowledgeable professionals in order to analyze materials and test working hypotheses; member checks-verifying both data and interpretations with study participants.

Transferability refers to the degree to which a study's findings can be applied in other contexts or with other participants. Transferability is like external validity within a positivist paradigm in which the findings of the study can be generalized to other

situations (Lincoln and Guba, 1985). However, the term transferability is more suitable within qualitative research to deal with its findings, which depend on the degree of similarity between the context of the research study and the context of audiences (Lincoln and Guba, 1985). Researchers generally use a rich, thick description to enhance transferability, which provides enough description so that other researchers are able to determine closely whether or not their situations match the research situation, and an audience can make a decision as to whether research findings can be transferred (Lincoln and Guba, 1985; Merriam, 1998; Coll and Chapman, 2000). Multi-case study is another technique used to enhance transferability within single case study research (Merriam, 1998).

Dependability refers to the stability of the findings if the study is repeated, coupled with the ability to explain any variations (Lincoln and Guba, 1985). To enhance dependability, the researcher should explain the assumption and theory behind the study, by triangulating data, leaving an audit trail, and describing in detail how the study was conducted and how the findings were derived throughout the inquiry (Merriam, 1998). These processes and products of data collection and analysis should be examined and reviewed by auditors to give the researchers feedback on the accuracy of their points of view (Lincoln and Guba, 1985).

Finally, confirmability refers to which findings of the study is the result of the study and not of the biases of the researcher (Lincoln and Guba, 1985). To increase confirmabiltiy, the researcher can employ an audit trail (Lincoln and Guba, 1985; Coll and Chapman, 2000). The audit process involves an internal audit regarding the researcher's explanation of the methods of data collection and analysis and theory behind the research study, and an external audit which allows an external person to assess both process and product of the research study (Merriam, 1998).

Research Design of the Study

The design of the research reported here is divided into two main phases according to the research objectives. The first phase describes data collection and

analysis to explore how the chemistry teachers performed their teaching practices before participation in the collaborative action research group. The second phase describes data collection and analysis during the teachers' participation in the collaborative action research procedure, and attempts to understand how the chemistry teachers changed their teaching practices based on constructivist principles. In order to study the teaching of in-service chemistry teachers, multiple data sources have been used during the research process. These were: observation, semi-structured interview, and document reviews. To investigate the usual teaching practices and their teaching changes, interpretive multiple case studies were employed as a research design. The timeline of data collection is shown in Table 1.

Table 1 Data Collection and Timeline

Phases of Study and Research Questions	**Participants**	**Methods of Data collection**	**Timeline/Number of data collection**
First Phase			August – September 2008 (Academic year 2008)
RQ I: How do chemistry teachers perform their teaching practices before participation in the collaborative action research project?	Three chemistry teachers from three schools	Classroom observation	Two lessons monthly per teacher (2 – 4 periods a lesson)
		Interviewing	After teaching each lesson (30 minutes)
		Lesson plan	Two lesson plans monthly from each teacher
Second Phase			November 2008 – March 2009 (Academic year 2008)
RQ II: What is the influence of a Collaborative Action Research project on the chemistry teachers' teaching practices based on a constructivist approach?	Three chemistry teachers from three schools		First Cycle (Nov 8th – Dec 5th, 2008)
		Group meeting	One meeting
		Classroom observation	Two times for two lessons each teacher (2 – 6 periods a lesson)
		Interviewing	Before and after teaching each lesson (30 minutes each time)
		Lesson plan	Two lesson plans each teacher
			Second Cycle (Dec 6th – Jan 9th, 2008) Similar to first cycle
			Third Cycle (Jan 10th – Mar 13th, 2008) Similar to second cycle

Context of the Study

This section provides background information, including a characterization of the chemistry teachers who volunteered to participate in this study, and a description of the processes involved in the collaborative action research project.

Participants

The participants of this study were three in-service chemistry teachers, Miss. Dara, Mrs. Aree, and Mrs. Benja (pseudonyms), teaching at different secondary public schools under the Bangkok Educational Service Area, Office 2.

Table 2 Participants' General Information

Topics	Dara	Aree	Benja
Academic Qualifications	Bachelor Degree in Education (B.Ed) Major: Chemistry -Master of Arts (Environment)	-Bachelor Degree in Education (B.Ed) Field: Secondary Education Major: Chemistry -Master of Science Program: Science Education (Chemistry)	-Bachelor Degree in Education (B.Ed) Field: Secondary Education Major: Chemistry -Master of Arts in Teaching
Professional Development	-Training in teacher college (focusing on the teaching of chemistry) -Attended workshop on the development lesson planning based on Backward Design	Attended workshops on -chemistry content -developing instructional materials -designing lesson plan	Attended workshops on - chemistry content knowledge - cooperative learning; STAD, Jigsaw, GI and LT - constructivism - designing lesson plan, instructional materials
Teaching Experience (years)	30	30	31
Chemistry Teaching Experience (years)	21	29	31
Teaching Responsibilities in 2008 academic year	Teaching Science at Grade 8, and Chemistry at Grade 10	Teaching Chemistry at Grade 10	Teaching Chemistry at Grade 10, and 11
Teaching Workload a week (periods)	17	19	18

Table 2 (Continued)

Topics	Dara	Aree	Benja
Academic standing	None	The expert teacher	The expert teacher The core teacher of science
Description of School	Public secondary school (grade 7-12)	Public secondary school (grade 7-12)	Public secondary school (grade 7-12)
School-size	Large	Extra-Large	Extra-Large

Their schools were three different co-educational government secondary schools under the Bangkok Educational Service Area, Office 2. The schools included third level-lower secondary education grades 7-9 (lower secondary level) and fourth level-upper secondary education grades 10-12 (upper-secondary level). At the upper secondary level, students were divided into science and non-science streams. Chemistry was divided into two main courses: fundamental chemistry, as part of general science, and taught to both science students and non-science students; and advanced chemistry, taught only to science students. Fundamental chemistry was one period a week. Advanced chemistry was taught three periods a week. One period was fifty minutes. Their educational background and teaching context are described here in each case of study.

Case of Dara

Dara had taught in Serm Wittaya Schools, where her present work place was, for 21 years. She taught general science and chemistry. In the 1977 academic year, she began her teaching career as a science teacher for lower secondary students at one secondary school in her hometown in the north-east part of Thailand, and continued there from 1977 until 1988 when she went on to become a Chemistry Teacher at Serm Wittaya School. The school focuses on developing an individualized learning where students' progress through a curriculum of concepts and skills at their own pace. The school's official goals are to develop students and teachers to meet the following characteristics: student is educated at his/her own pace; the student is to develop a higher self-esteem and a sense of self-worth based on the philosophy of economic

sufficiency; and the teacher is to be knowledgeable and understandable in teaching, in accordance with the National Education Act 1999.

Based on the school year book report in 2008, the school had 123 teachers, of whom 19.51% (24 teachers) were males and 80.49% (99 teachers) were females. Nineteen teachers comprised the science department. Most teachers (63.5% or 97 teachers) had a Bachelor degree. The school had 2,171 students: 1,067 males and 1,104 females. There were 60 classrooms divided into lower secondary level and upper secondary level. In lower secondary level, the number of classroom at grades seven to nine are 12, 14, and 14 classrooms respectively. In upper secondary level the number of classroom at grades ten to twelve are 6, 7, and 7 classrooms respectively.

Serm Wittaya School is located in a residential area containing a slum, official institutions, stores, and a temple. The majority of students' parents were Buddhist. The remainder had Christian and Muslim parents. As to their education, most students' parents graduated with lower Bachelor's Degrees, about 59.55%. As to their occupations, 52.25 % of students' parents are employees. The others are government officers (20.90%), state enterprise officers (9.73%), vendors (14.41%) and others (2.71%). The majority of parents are in the middle and low socio-economic status range. The average income of each family is about 96,000 Bath a year. The average number of members is about 3-4 person per family.

One class of grade 10 students learning with Dara participated in this study. There were forty four students, fifteen males and twenty-nine females. The students' capability in this classroom was in the middle group, between the highest and lowest group of other Science and Mathematics Program classrooms. When learning chemistry, in the first semester of the 2008 academic year, they were in one of several laboratory rooms specified for chemistry experiments. The teacher' desk which was about 2.5 meters long was placed in front of the laboratory room. On top of the teacher's desk, there was a sink. There was one cupboard placed at the back. At the other side of the laboratory room, near the windows, there were four sinks. There were six tables and about fifty five chairs in the classroom. During study, the students were divided into six groups and sat around tables as shown in Figure 1

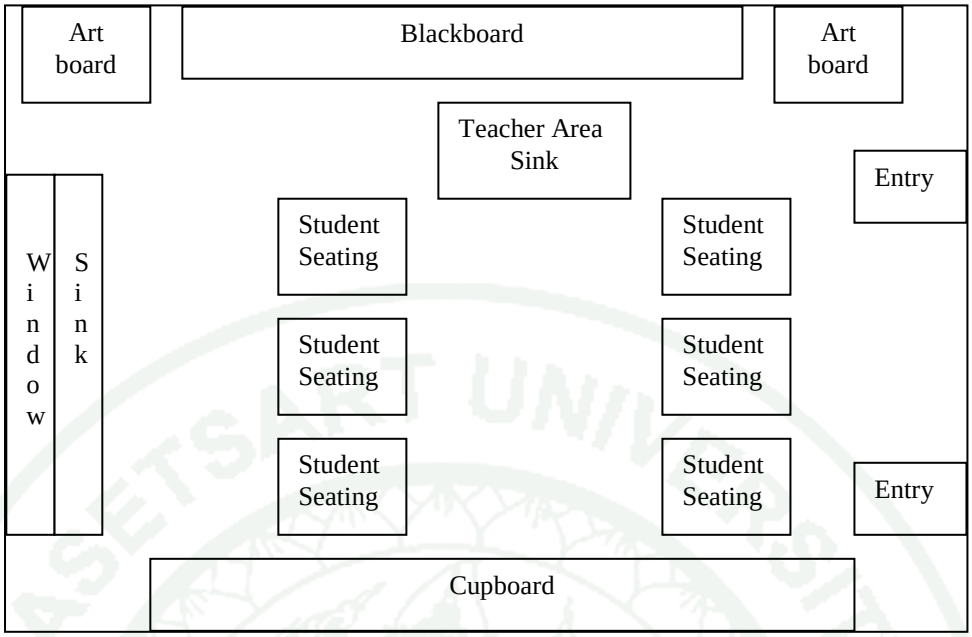

Figure 1 Layout of Dara's Classroom

However, due to insufficient laboratory room for all groups of students, in the second semester these participants had to study in regular classrooms not appropriate for conducting experiments. In this classroom there were six different-sized tables and about fifty five chairs in the classroom. During study, the students sat around tables with a different number in each group depending on size of the table.

Case of Aree

Aree was an experienced teacher. She typically taught general science and chemistry. In the academic year 2008, she taught 19 periods a week, worked in the school policy and planning division, and was a mentor for one classroom of Grade 11 students. Her school, Siriwittaya School, focuses on developing an individualized learning where students progress through a curriculum of concepts and skills at their own pace. Based on the school's official policies, the school aims to: develop students with a balance between physical and mental qualities, equip students with good morals and a sense of responsibility to society and encourage them to successfully apply the philosophy of economic sufficiency to real life, and to support teachers so as to enable

them to organize the learning process around the learner as the most important person who can learn best at his/her own pace.

In the academic year 2008, the school had 164 teachers consisting of 139 females and 25 males. Most teachers (75.61% or 124 teachers) had a Bachelor degree. The school had 4,453 students; 2,034 males and 2,419 females. There were 92 classrooms divided into lower secondary level and upper secondary level. In the lower secondary level, the number of classrooms for grades seven to nine were 16, 16, and 15 classrooms respectively. In the upper secondary level the numbers of classrooms for grades ten to twelve were fifteen classrooms for each grade level.

Siriwittaya School was located in a residential area containing official institutions, stores, and a temple. The majority of students' parents were Buddhist. The remainders had Christian and Muslim parents. As to their education, approximately 70.00% of students' parents graduated with Bachelor's Degrees, approximately 70.00%. As to their occupations, about 46.08% of students' parents were government officers. The others were employees (41.24%), vendors (11.52%) and farmers (1.15%). The majority of parents were of good socio-economic status range.

Within this study, forty-five students in one classroom of Grade 10 students, thirteen males and thirty two females, who studied chemistry with Aree participated in this research study. The average student's G.P.A in this classroom was in the average of other Science and Mathematic Program classrooms. This group of students in general did pay attention to their study. As to the classroom context, the room used in both the first semester and the second semester was one of several laboratory rooms. The teacher's desk which was about 3.0 meters long was placed in front of the laboratory room. On top of the teacher's desk on the left hand side, there was a sink. There were two cupboards placed at the back, and another one placed at one side of the laboratory room, near the wall. At the other side of the laboratory room, near the windows, there were four sinks. There were six tables and about fifty chairs in the classroom. During the study, the students were divided into six groups and sat around tables as shown in Figure 2

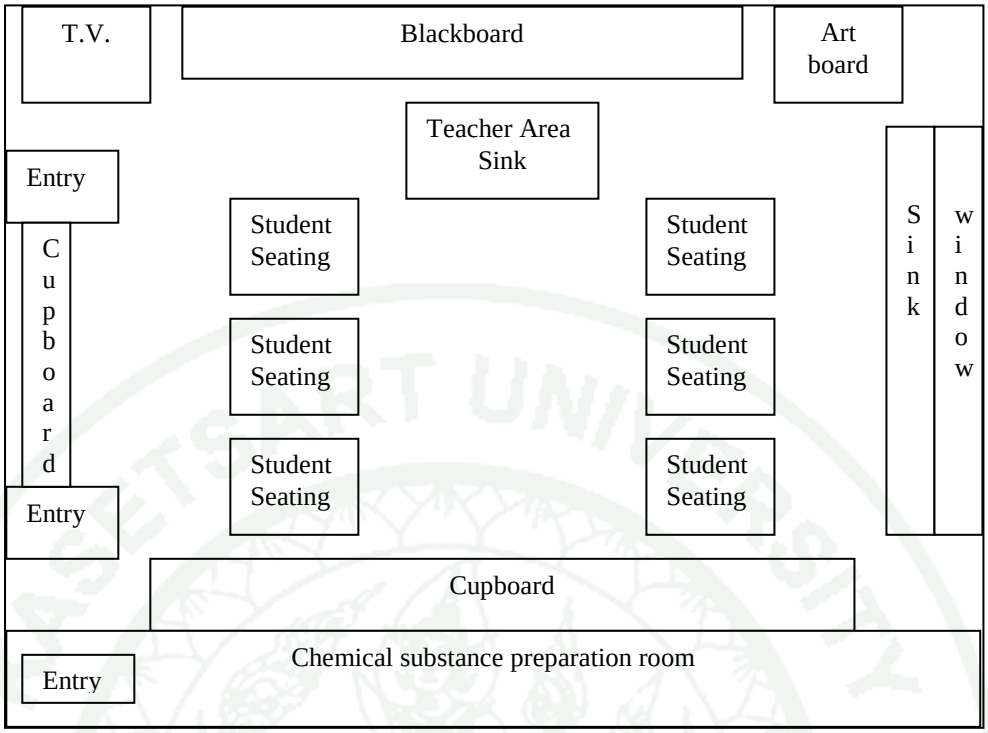

Figure 2 Layout of Aree's Classroom

Case of Benja

Benja had 33 years' teaching experience and 32 years' chemistry teaching experience. In the academic year 2008, she taught 18 periods a week, mainly in basic chemistry, and additional chemistry for tenth grade students for 4 periods a week and eleventh grade students for 12 periods a week. She also worked as the science department deputy chief and was a mentor for Grade 11 students.

According the school annual report of 2008, her school, Prachabumrung School, focused on developing an individualized learning followed the basic education standard where students themselves were able to successfully apply a philosophy of economic sufficiency to real life. Based on the school annual report, the school had 166 teachers, consisting of 126 females and 40 males. Most teachers (75.51% or 125 teachers) had a Bachelor degree. The school had 3,319 students; 1,464 males and 1,855 females. There were 76 classrooms divided into lower secondary level and upper secondary level. In the lower secondary level, the number of classrooms at grades seven to nine are 16, 15,

and 15 classrooms respectively. In the upper secondary level the numbers of classrooms at grade ten to twelve are 10, 10, and 9 classrooms respectively.

Prachabumrung School is located in a residential area containing official institutions, stores, and a temple. The majority of students' parents were Buddhist. The remainders had Christian and Muslim parents. As to their occupations, most students' parents were vendors and employees. The majority of parents were in the middle and low socio-economic status range.

Forty-nine students in Grade 11, twenty males and twenty-nine females, had studied chemistry with Benja and participated in this research study. The average student's G.P.A and their capability in this classroom were in the second group of three Science and Mathematic Program classrooms. Even though they were not as expert as the first group, they could organize their learning process well, and paid attention to their studies.

In the first semester of the 2008 academic year, these groups of students were taught in one of the classroom laboratory rooms. The teacher' desk, which was about 2.5 meters long, was placed in front of the laboratory room. On top of the teacher's desk, there was a sink. There was one cupboard placed at one side of the laboratory room, near the window. At the other side of the laboratory room, near the windows, there were four sinks. There was one computer and one book shelf at the back of the room. There were six tables and about fifty chairs in the classroom. During study, the students were divided into six groups and sat around tables as shown in Figure 3

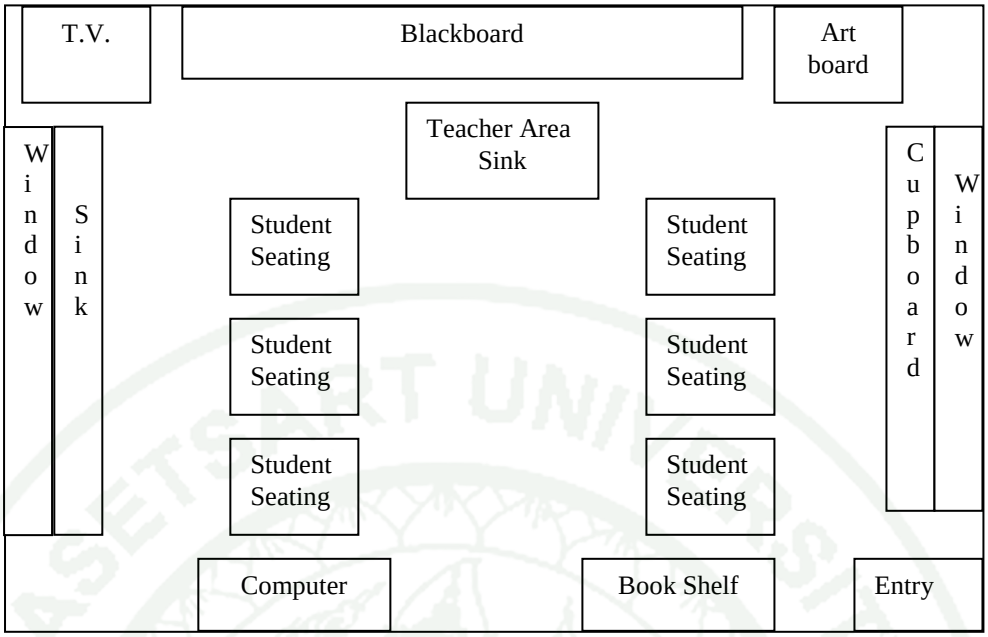

Figure 3 Layout of Benja's Classroom

However, in the second semester this class had to move and learn in another room into the new building, the new room being one built for conducting experiments. Yet its construction was not completely finished. There were neither sinks for running water nor cupboard for any chemicals or instruments. The room just provided nine tables and sufficient chairs for the students to sit around them.

Collaborative Action Research Program

In educational reality, action research is used as means for professional development, and or problem solving in a variety of work situations (Kemmis and Wilkinson, 1998). Aiming to enrich the teachers' teaching based on the constructivist approach, the collaborative action research project [CAR] was developed, which fulfilled the characteristics of the collaborative action research approach as discussed in the previous chapter, including such factors as: a) collaboration, b) partnerships, c) focusing on common problem, d) sharing power and ownership, e) focusing on practice in recurring cycles of planning, acting, observing, reflecting, and revising or modifying the plan, and f) teachers' professional growth. The following section provides

descriptions of the purpose, the CAR group members, the roles of CAR group members, and the procedure of CAR.

Purpose of the CAR

The purpose in using collaborative action research in this study is to enhance teacher's practice based on the constructivist approach. The three teachers could define their own problems and issues freely, without being manipulated, and then investigated their own practices by using their data sources to explain particular phenomena, posed new questions, and improved subsequent actions based on what they had learned in their own practices, and shared their experiences collaboratively via recurring cycles and meetings of CAR group members who were aiming to learn and then changed their practices in accordance with the constructivist approach.

CAR Group Members

In this study, there were five members who had the common purpose of promoting the chemistry teachers' understanding and practice in teaching based on constructivist approach, and who participated in our CAR group. There were three chemistry teachers who taught at upper-secondary level, one researcher, and one science educator.

Role of CAR Members

Role of Researcher

Before entering the research process, I needed to be consciously aware of how to interpret my role. As regards the researcher's activity in the research process, there were two perspectives from which to see the researcher's role. The first perspective was that of the researcher and the second was that of the facilitator. From the literature on action research, it was clear that those who researched and facilitated the process of action research had engaged themselves to offer advice and support on

research techniques as well as theoretical perspectives (Kemmis, 1990). As facilitators, they had greater opportunity to narrow the theory and practice gap and help teachers or participants to understand where they wanted to go (Kosmidou and Usher, 1991). However, I as facilitator had to constantly deliberate about my practice and its relationship to the nature of the activity I was trying to facilitate. I had to be careful not to intervene too strongly, for fear that the teachers as researchers would lose intellectual control of their own research work (Kemmis, 1990).

My role as a researcher meant that when I myself discussed the research study with members of the teachers group and the science educator who was called facilitator 2 in this study, I had to be aware of my behavior and its impact. By developing a level of self-consciousness, I took steps toward honoring the privacy of the participants and the responsibility of conducting the research. As a researcher, I came to learn from and with the teachers in the collaborative action research group by listening from them how they addressed issues in their own classrooms. As the result of conducting research, I could learn from the teachers and reflected on several aspects of the research findings as a part of learning.

Another role I played as facilitator was to foster collaboration and support for the participants in identifying and pursuing their goals and meeting their expectations. The facilitator role that I chose to play in this collaborative action research study was that of a participating facilitator/observer. Following Glesne's continuum, I identified my role in this study as that of a full participant (Glesne, 1999). As an observer and participant, I participated in the group meetings, interviewed the teachers, and observed the teachers in their own classrooms.

Role of the Teachers

The teachers' roles were as important as the researcher's role in the research. In this study, as members of the CAR group the teachers participated in group meetings, discussed with me, worked on their lesson plans, and performed and reflected on their practices. The teachers had the freedom to innovate, make a decision, and

perform according to their needs, experience, understanding, and the situation in which they conducted their teaching.

Role of the Science Educator

As a CAR group member, the science educator became another facilitator who was called facilitator 2. As facilitator, she helped the teachers to apply the theory of constructivist approach into a practice suitable to each teacher's school context. The facilitator 2 played the supportive role in helping the teachers recognizes different ways to initiate and implement change within their own context. She listened to the teachers' stories, shared the same interests, and shared some content knowledge and pedagogical content knowledge. However, basically facilitator 2 interacted face-to-face with CAR members only in the group meetings.

Data Collection and Analysis in First Phase

Data Collection

In order to study the performance of in-service chemistry teachers, multiple data sources were used during the research process. These were: classroom observations, semi-structured interviews, and review of documents.

Classroom Observations

Participant observation was a major data gathering technique during the first phase of my study in the three schools during August to September 2008, in the first semester in the academic year 2008. It was used in this phase to investigate how the teachers performed their teaching, how their students responded, and how the teachers' interacted with students in their classroom setting. Each teacher was observed a total of four times in the four lessons. By this technique, I had to immerse myself in the classrooms. Therefore in order to build up a rapport with students and become part of the classroom context, before collecting the data on the teachers' practice I visited

the classrooms in July 2008. This was to gain a close and friendly familiarity with teachers and students and their practices.

The purposes of observations were similar every single time in terms of investigating teacher teaching. However the focus of observations any time was slightly varied based on the activities in each classroom such as experimental activities, group work, or learning assessment. I observed those activities and events in each class that were significant to teaching based on the constructivist approach and its components.

During classroom observation, field notes were taken immediately, and videotaping was also used to collect the data. There were two purposes for using videotaping. The first purpose was so that the teachers could review their teaching afterwards by watching the videotape. Another purpose was that I could obtain data from it that field notes could not capture, such as dialogues and classroom discussion.

Semi-structured Interviews

Semi-structured interviews were employed to interview teachers after they had completed teaching each topic. Semi-structured interviews were aimed at gaining insight into how teachers taught, and focused on: teaching methods employed, reasons for employing those teaching methods, and evidence of student's learning as a result of the teaching methods employed. The teachers were also asked to reflect on the lesson they had just taught in terms of the strengths and weaknesses of their teaching. During interviews, the researcher took notes as much as possible, and tape recording was used to help the research collect comprehensive data.

Review of Documents

To investigate the teachers' teaching, lesson plans for teaching chemistry generated by the teachers were collected and examined. The teachers were asked to choose chemistry concepts and to plan lessons for teaching those concepts. Beyond lesson plans, the teachers were asked for worksheets and learning assessment

tools as documents for review. The chemistry textbooks and teacher manuals also were collected to review.

Data Analysis

The research focus of the first phase for this study is how chemistry teachers perform their teaching practice. Through the data analysis methods, I attempted to discern patterns in their practices. The approach to analysis involved an inductive process to search for correspondences and patterns, from which one could then establish themes. The data analysis methods primarily began with within-case analysis to investigate each teacher's practice, followed by cross-case analysis. The data was transcribed and/or analyzed as described below.

Observational data from videotaped observations were transcribed. The transcripts of observational data were triangulated with field notes to discern teachers' perspectives and their practices. Interview data from all audiotaped interviews were transcribed verbatim and written up, using a pattern similar to field note observations. Other documents such as a teacher's lesson plans, learning assessment tools, chemistry textbooks and teacher manuals were brought together.

This part aimed at examining the practices in teacher's teaching. The several sources of data were compared. I identified specific events and activities that were either representative of the teacher's practice in line with traditional teaching or more characteristic of constructivist teaching. The analysis of these data focused on the identification of regularities or patterns in the statements made by the participants, without the use of an a priori established system of categories or themes. Instead, I developed themes on the basis of the data. The data from different sources were compared with each other, as well as with main points related to the teachers' practices.

The final phase of analysis involved cross-case analysis. The cross-case analysis was used to make comparisons across the three cases. Their teaching practices which were similar to traditional teaching and constructivist teaching were interpreted in

terms of general patterns and regularities. Similarities and differences were interpreted in the light of information about individual contexts and personal background.

In the second phase, the CAR group meetings were developed by considering information from the preliminary data of the first phase study, a literature review of teaching and learning based on the constructivist approach, action research as professional development strategies, science education in the Thai context, and the existing science standard in teaching chemistry.

Data Collection and Analysis in Second Phase

Data Collection

In order to study how the teachers changed and applied their new understandings about constructivist principles in their classroom during participation in this study, the second phase of the research study was begun. There were three cycles of collaborative action research. The first cycle took place from November 8th to December 5th, 2008. The second cycle, December 6th, 2008 to January 9th, 2009 and the third cycle, January 10th to March 13th, 2009. The activities in each cycle consisted of one group meeting held at Kasetsart University, which occupied approximately 3 hours. After the group meeting I had one-to-one individual teacher meetings to help the teachers design lesson plans which could be implemented within their own classroom settings. Furthermore, to understand how each teacher performed and changed their practices I did classroom observations, interviews, and analysis of teachers' lesson plans as well as other related documents, 1-2 lessons a cycle based on what they were teaching.

The Meetings of the CAR Group

Group Meeting 1

In November 8th, 2008, the teachers were invited to the first group meeting at Kasetsart University to revisit the purpose and nature of the research study.

At the beginning of the meeting, I introduced myself and all CAR group members to each other. This was followed by introducing an outline of the CAR group activities in this first meeting. Then an overview of the CAR in this study, as well as the rationales for enhancing teacher teaching practice through CAR, was presented. For the first activity, the teachers were asked to reflect on their current teaching practices. After the discussion, I summarized the teaching methods each of the teachers had used in their teaching. Before introducing the teachers to the next activity, I had them discuss their own understanding of any aspect of constructivist principles. Facilitator 2 and I posed some questions for guiding the teachers to an understanding of some aspects of the essential principles of the constructivist approach, including the students' prior knowledge, teaching and learning activities under the principles of the constructivist approach, and the teacher's role. However, it is important to note here that at this stage the teachers did not yet know exactly what the essential principles of the constructivist approach of this study were. Therefore, the aim of this activity was to prepare the teachers for the next activity, in which they were asked to share their thoughts in generating the essential principles of the constructivist teaching approach.

In the second activity, after the teachers had discussed the constructivist teaching approach based on their limited understanding of only some of its essential principles, I then introduced to them the constructivism framework for teaching as derived from various documents. After the discussion, our group finally reached agreement on four aspects of the constructivist teaching approach, which included: 1) the importance of student's prior knowledge, 2) the teaching and learning activities, 3) social interaction, and 4) the learning assessment.

In the third activity, to promote the teachers' understanding of constructivist principles, the teachers were asked to analyze on their own teachings' practice as to whether or not it was consistent with constructivist principles. As a way to promote teacher learning together, the group changed the activity from reflection on their own teaching to critiquing only one case of that practice. Under this agreement, Benja volunteered to present her teaching practice by having other CAR group members watch her practice through video presentation. In sharing and discussing among group members, I posed some questions to prompt the teachers in thinking

about what main features of constructivist principles were evident in Benja's practice. However, it should be noted here that this was the first time for some teacher to learn about the constructivist approach. Some teachers still kept quiet and listened to other members. Therefore, aiming to help the teachers to see a concrete example of constructivist teaching in a classroom setting, I presented one lesson plan on the concept of ionic bonding. This lesson plan was developed by me on the suggestion of facilitator 2.

Before the end of the first meeting, I discussed the role of the researcher and the teachers, as well as the teachers' responsibility in the collaborative action research group to make a tentative schedule for data collection, to identify avenues for classroom observations, and to arrange for one-to-one individual teacher meetings with me, and group meetings. To track the change and foster reflection on the practice of each teacher in each cycle, I scheduled meetings with all teachers at appropriate times, at least one a month.

Group Meeting 2

The second group meeting was held on December 6th, 2008. The aim of this meeting was to provide the teachers with an opportunity to reflect on their teaching practices and students' learning as a result of integrating constructivist principles into their teaching practices. Another aim of this meeting was to provide the teachers with an opportunity to learn together how to design lesson plans and learning activities. After informing the teachers of the overview of the second group meeting, I immediately initiated the group activities.

In the first activity, the teachers were asked to share their experiences after the first cycle of CAR. They reflected on how they integrated the constructivist principles into their teaching, the students' success in learning, and feedback received on their new teaching approach. Then the teachers began to discuss about the problems they faced in their teaching practices due to the integration of constructivist principles into their teaching and learning activities. After the group discussion, I summarized the common problems that all teachers were encountering, consisting of: questioning,

incorporating cooperative learning into their classroom, and a lack of time to implement their lessons. The group discussed how to solve all these problems together. However, it was noted here that there was no specific pattern of a solution because so much depended on classroom context. What we talked about focused on enriching the teacher to increase their understanding of teaching based on constructivist approach.

In the second activity of this group meeting, the teachers learned together how to design lesson plans with integrated constructivist principles. Aree asked to be a volunteer to present her lesson plan so that other CAR group members could give her comments or suggest designing learning activities which embodied constructivist principles. In addition she wanted to convince herself that she had a correct understanding of the constructivist approach. In this activity, Aree presented her lesson plan, and other group members gave suggestions on each step of her teaching and learning activities.

At the end of the second group meeting, I briefly summarized the group activities and what we had learned together. I then asked teachers to make a tentative schedule for the next meeting.

Group Meeting 3

The third group meeting was held in January 10th, 2009. The aims of this meeting were similar to the second group meeting: to provide the teachers with an opportunity to reflect on their teachings' practices and their students' learning as a result of integrating constructivist principles into their teaching practices, and to provide the teachers with an opportunity to learn together how to design lesson plans based on the constructivist approach. After giving the teachers an overview of the third group meeting, I immediately began the group activities.

Because there were two teachers asked to present their lesson plans, therefore the first activity to reflect teachers' experience was taken place quickly. Then Benja began to present her lesson plan. As well, she commented as to whether or not

her lesson plan was consistent with the teaching based on the constructivist approach. While Benja presented her lesson plan, the other members gave her suggestions. After Benja, Dara presented her lesson. At the end of the second group meeting, I briefly summarized the group's activity and what we had learned together.

In order to examine how the teachers changed their approach and applied their new understanding of constructivist principles in their classrooms, the following multiple data collection and data sources were used in the research process: participation in group meetings, classroom observations, semi-structured interviews and review of documents.

With the teachers' permission, group discussions in each meeting were videotaped. The group session's transcripts of the recorded sessions were used to explore ways that the teachers thought, constructed meaning, and reflected upon their changes. Because I also was the facilitator during group meetings, I participated and interacted with the teachers. This participation helped me access the information of participants. During the group meetings I took notes as a way of keeping an active record of what was discussed. On the other hand, the note taking supplied summaries of the meeting and of the ideas discussed in it. These summaries served two purposes: 1) to record the teachers' concerns, and 2) to record the teachers' accumulated knowledge. However, the researcher as the facilitator did not find it convenient to take many field notes. The field notes in this case were therefore taken immediately after the meetings.

Classroom Observations

The classroom observations were conducted during the implementation of the teachers' lesson plans. Each teacher was expected to be observed twice a month. During class observation, I acted as a non-participant observer making descriptive notes of the events, activities, and dialoging that took place in the classroom. The lessons also were recorded using videotape to collect detailed data of teachers' teaching practice that I could not capture in my note.

Semi-Structured Interviews

To further track the practice of each so that I could look for possibilities in consultation with the teachers, I worked alongside to advise and guide the teachers to design tasks and strategies for their classrooms. I scheduled discussions on a one-to-one basis with each teacher at appropriate times. Before classes, I used semi-structured interviews to investigate each teacher's understanding of teaching based on the constructivist approach. The teachers were asked to answer open-ended questions related to their lesson plans, regarding how they integrated the constructivist approach into their teaching and learning activities: planning, preparing, and teaching. In addition the teachers' experiences about their previous teaching were also queried so as to explore meanings that these experiences held for them and that might impact on their practices. With the teachers' permission, conversations were audio recorded.

Another semi-structured interview was conducted to investigate each teacher's understanding about teaching based on the constructivist approach, to discover what they had changed in their practices in line with the constructivist approach, and to uncover factors that might enhance or hinder their teaching. The teachers were asked to attend an interview after they had completed their teaching in each lesson. The interview was audiotaped. The data from the audiotape helped me access in-depth data from teachers and supported classroom observation data. The recordings were transcribed and shared on a regular basis with the teachers for comments, accuracy, and validation.

Review of Documents

I collected teachers' lesson plans for teaching chemistry. The data from lesson plans, interviews, and observations gathered were triangulated. The teachers' lesson plans and related documents such as handouts and worksheets provided me with data related to changes the teachers' practices had undergone, and alerted me to factors enhancing and hindering their development in teaching based on the constructivist approach.

Data Analysis

The research focus of this phase is whether or not the teachers changed their practice during participation in the collaborative action research group. In the analysis of the data collected, I identified patterns from multiple sources. The approach to analysis used here involved an inductive process: a search for correspondences and patterns and finally establishing themes of the research findings. Like the methods of analysis in the first phase, within-case analysis was made prior to cross-case analysis. To examine the change in the chemistry teachers' teaching base on constructivist approach during their participation in the collaborative action research group, the interviews were transcribed verbatim and triangulated with field notes from observation and lesson plans. These data were read, coded and categorized using inductive analysis. The final phase of data analysis involved cross-case analysis. The cross-case analysis was used to make comparisons across the three cases. Similarities and differences were interpreted in the light of information about individual contexts and personal backgrounds.

Ethical Considerations

To protect the rights of the teachers as participants in this study, I constructed an informed letter for data collection. This letter included a brief description to introduce the researcher, the plan of the study, and the need to conduct interviews and observations. It asked for teachers' lesson plans, explained how the information collected was to be used, and how the participants could expect to be rewarded for their participation. This letter was submitted to the researcher's advisor for approval prior to the start of the study. The letters were sent to all the teachers and principals of the schools in which teachers worked. Before I began my study, I reviewed the contents of the letter with each teacher, in order to answer any questions they had about their participation in the study.

A number of steps were taken to ensure the privacy and confidentiality of all involved, so that participants would feel that they could share freely and openly. A

guarantee of anonymity was given to all teachers and students associated with the project. Pseudonyms would be used for all names and the identities of all participants. Upon the completion of each interview and classroom observation, I provided each teacher with a copy of the interview transcripts and field notes from the classroom observation. All data collected during the study were stored in a secure place, and then were to be destroyed following the researcher's dissertation defense date.

Strategies to Enhance the Trustworthiness of the Data Collection and Analysis

Trustworthiness for this study was ensured by the use of triangulation of data and methods. Data collection methods employed in this research study involved several techniques, including interviews, classroom observations, and document collection. The creditability was additionally increased by a member checking technique, in which each participant was given a copy of the observations or interviews to recheck their answer after interviews or observations.

Enhancing transferability, I wrote in-depth descriptions and used multi-case studies and thick description in the research study to explain the context of the situation and the findings. I described the context of the situation being studied in detail, in order to provide an opportunity for the readers to evaluate the feasibility of applying the study to their own situation. Multiple case studies were also employed to enhance the transferability of the research study. I used three cases. In this study, each case (participant) had different perspectives, knowledge bases, beliefs, and background and each was in a different context. The analysis of each case and cross-case analysis provided detailed descriptions from all cases and increased the transferability the study.

Working with my advisers facilitated the dependability and conformability of the data collection and analysis as an ongoing process. The advisers also acted as an external auditor to check each step of the inquiry process. For all steps of data analysis, I met with the advisers to discuss and to gain a consensus on the findings. Then the advisers and I discussed the tentative claim from data analysis. Where I and the advisers held different views of the data, I re-analyzed the data and discussed my

results with the advisers to obtain an agreement on findings. The advisers gave feedback on ideas, and fostered insights, thereby adding to the study's credibility.

Summary

This chapter presents the research methodology relating to examining how chemistry teachers perform their teaching practices before participation in the collaborative action research project, and to investigating whether or not chemistry teachers change their teaching practices as an influence of their participation in a collaborative action research group. To answer the research questions, an interpretive case study research was employed. The research study started with a first phase: to find out the nature of teachers' chemistry teaching in secondary school. Then these findings were used as one of the guiding principles in the process of improving the practice of teachers through collaborative action research program. The research employed a number of data gathering techniques – classroom observations, interviews, review of documents and participation in group meetings – to find out if the collaborative action research impacted on the teachers so as to change their practices along constructivist lines. Analysis of data from these different sources, and persistent observation, and cross-checking were undertaken to enhance the trustworthiness of the research findings. The analysis approach consisted of an inductive process to search for correspondence and patterns. The changes in teachers' teaching practices based on the constructivist approach were analyzed and linked together to formulate themes to explain the meaning of the research findings. The ethical dimension was taken into consideration in all stages of this study. The next chapter presents results of the first phase of study about chemistry teachers' teaching practices in the first semester of the Thai 2008 academic year.

CHAPTER IV

RESULTS OF PHASE I OF THE STUDY

Overview of the Chapter

This chapter provides the results of the analysis of the multiple data sources used to answer the first research question, namely: "How do chemistry teachers perform their teaching practices before participation in the collaborative action research project?" The chapter presents three cases of in-service chemistry teachers. Within each case, personal and educational background, and the teacher's teaching practices are presented. The practice is presented by creating themes relevant to the class learning activities. Themes of teacher teaching practice of each case are presented in the following sections including: lesson introduction, teaching and learning process, social interaction in classroom, learning assessment, and finally teacher roles. The chapter ends with a summary of common findings that emerged from a cross-case analysis of these chemistry teachers. Throughout the chapter, pseudonyms, (Dara, Aree, and Benja), are used to protect the chemistry teachers' identities. Throughout the first semester in the Thai academic year 2008, the three chemistry teachers were observed four times, and interviewed four times after their teaching. In addition, they were asked for four lesson plans based on topics they had allowed for observation.

The Case of Dara

Dara's Background in Relation to the Constructivist Teaching Approach

Miss. Dara has had no experience with or has not attended any workshops focusing on the constructivist teaching approach. She personally views the constructivist teaching approach as one in which students play an active role in their learning process. As a consequence, students construct their own concepts by manipulating concrete objects and through hands-on activities. In her opinion, the

teacher need not act as a support pillar for students to lean on. Students have to actively participate in their learning process.

In Dara's opinion, there are limitations to using the constructivist approach in her classroom. Firstly, it is time consuming, because it needs more time to use the strategies which can monitor the construction of each student's knowledge. Secondly, she has to cover all content framed for her course, and this does not allow her to teach based on the constructivist approach. As mentioned here, it is an overview of Dara's opinion and her previous experience which influence on her subsequent teaching practice.

Dara's Teaching Practice

In this section, the results are discussed in terms of Dara's practice as shown in the activities in her classroom. The data were collected and teaching practices were observed in one classroom of 10^{th} grade students who were studying in the science program. The instructional unit observed was on ionic bonding, including four main concepts: ionic compounds; naming and formula writing; Born-Harbor cycle and energy of ionic compound formation; solubility of ionic salts; and reactions of ionic compounds.

Lesson Introduction

The Realization of Student's Prior Knowledge

In Dara's classroom, she always stressed trying to practice her teaching based on constraints imposed by school curriculum standards. Covering content matter in all topics took precedence over teaching deeply, so that students could use what they learned for the examination. She decided what students should learn and how. The instruction focused on providing content. Student needs and characteristics were not considered an important part of teaching.

Before teaching a new concept, Dara often told students what topic was being taught and how she would like them to handle it, such as having them do an experiment. Then she transmitted her knowledge with the expectation that students literally understand what she had said and that students could answer her questions correctly. For instance, on the topic of naming and writing ionic formulas the teacher began the class by declaring that they would learn in learning centers where she would provide instructional materials for students to do self-study. She then briefly explained the concept, naming and writing ionic compound formulas, which students were then going to study. She explained which materials were available, consisting of handout, worksheet, and answer key. She then distributed these materials to each group of students and had students studying them by themselves. Other examples: when teaching about ionic dissolving and ionic equations, the teacher only told students that they were going to learn by conducting an experiment. She asked them to formulate a hypothesis of the experiment. Then she told them the list of chemicals and instruments, the lab procedure, and what they should observe.

Some classroom observations revealed that she used questioning to review students' previous knowledge learned from the previous topic. For example, before teaching the main concepts of the Born-Harbor cycle and the energy of ionic compound formation, Dara reviewed what students knew about the previous topic by asking them some questions including: "What is the ionic formula of Sodium Chloride?" "What group is Sodium a part of? And what is the sodium ionic charge?" "Sodium is in group one and the ionic charge is positive, and what about Chlorine?" "Chlorine is in Group Seven. What is the ionic charge of chlorine?" and "How do you write the Sodium Chloride formula?" After the teacher had questioned students about ionic bonding, she then began the mini-lecture by writing the steps of ionic formation through the Born-Harbor cycle, using the formation of Sodium Chloride as an example, and then explained the procedure.

Even though Dara asked students for previous knowledge, she seldom used questioning and other class activities to inquire into student's prior knowledge as to how they thought about the new concept. She placed great emphasis on the faster

pace and greater bulk of knowledge transmitted from teacher to students. Therefore before teaching every topic she often told the students the information she would be addressing and wrote down topic titles.

Learning Activity

Lectures and experiments, followed by having students do the assignment, were the predominant teaching and learning activities in Dara's classroom.

The Teaching Strategies

Students were moved through the lesson by listening and responding in chorus to Dara's lecture. Dara was very concerned about instructional schedules and felt an urgency to comply with the school curriculum, which she believed did not allocate enough time for her to pose open-ended questions and wait for student responses. For this reason Dara devoted only a little of her instructional time to questions aimed at provoking thoughtful responses. On the contrary, she quickly began the class by stating the topic being taught, explaining the concept, and eventually asking students to copy down what she had said.

Particularly revealing of Dara's teaching practice was her handling of the concept of energy of ionic formation. She began the lecture by writing down the five steps of ionic formation through the Born-Harbor cycle, using the formation of sodium chloride as an example. To explain the first step she said that sodium metal was vaporized to a gas of sodium atoms. This step required an input of energy known as the atomization energy of sodium metal. Then she tried to compare the endothermic process of sodium vaporization with the real life situation by questioning; "Why do you feel cool when you rub alcohol on your skin?" But none of the students responded. She did not wait for students to respond but rather answered her own questions: "Because when you put alcohol on your skin, alcohol evaporates by removing heat from your skin so that it feels cold to you. Evaporation is a process that requires a lot of energy, so evaporation is an endothermic process."

She continued explaining other steps of ionic formation and interrupted with questioning: “What it is meant by ionization energy?” She again answered her own question and still kept explaining until she had covered all content matter. After finishing her explanation she told students that “you have to memorize all five steps of ionic formation, and after that I will give you the assignment in which you have to rearrange the steps presented to form the steps of ionic formation.” And then she asked students to copy what she had written on the blackboard into their notebooks.

Similar to the energy of ionic formation topic, in teaching other topics she used lectures as her primary teaching method to provide knowledge. She initially wrote the content matter being taught on the blackboard and followed by explanation and questioning. Students were asked to copy down what the teacher had explained for them.

The Opportunity to Do Hands-On Activity

Experiment was another method Dara used for her class. She explained, in the interview session after teaching, that in conducting the laboratory experiment, she did not allow all students to conduct the experiment themselves but rather used demonstrations by asking the representatives of each group of students to conduct the class experiment (depending on the availability of equipment and materials) instead. In general, when conducting class experiments, Dara prepared all instruments and chemicals and put them in front of the class in the teacher area. The activity was begun by the teacher stating the title of the experiment. Then she asked for the hypothesis, explained the lab procedure, asked randomly some representatives of each group to come to the demonstration bench to carry out selected steps of the experiment, had these students tell her the experimental results, and finally stated a conclusion for the students.

In one lesson, for instance, the teacher introduced the topic of ionic dissolving to students using an experimental demonstration to illustrate a change in

temperature. Before conducting the experiment, Dara first introduced lists of the chemicals used and then encouraged students to s formulate a hypothesis by asking; “Is there any difference due to solubility among the ionic salts provided?” And “Does dissolving of these ionic compounds affect temperature?” A number of students answered “Yes”. With this answer from the students, and with no further questions asked as to the reason for saying “Yes”, she herself wrote down the hypothesis on the blackboard and then drew a picture illustrating the experimental procedure. She explained step by step the experimental procedure in the class experiment. After that, she had representative students from each group take out the equipment. Two students from each group came to the front of class, took the chemicals, and conducted the experiment at that place, following the procedure written on the blackboard. Some students who did not understand the procedure clearly asked the teacher for step by step instruction, and then followed what the teacher had said, step by step. Others who did not conduct the experiment just sat waiting, and some even kept talking.

Dara then drew a data table and asked the representative students about the result of the experiment. Because the students did not get the expected results, Dara ran it again and recorded what she found without any discussion regarding the error in the students’ data.

Even though Dara believed she had taught the experiment, along with methods of inquiry consisting of hypothesizing, investigating, and conducting, there was no obvious evidence that these activities had increased students’ understanding of the material being taught. As to the utility of students conducting an experiment to further their understanding, Dara said:

> They do not understand much while conducting the experiment. They can learn when I tell them. The reason for using the experiment is to change classroom atmosphere from lecture to experiment that students are given the opportunity to touch some equipment. (2nd Interview: Dara, Sep 1st, 2008)

The Student's Responsibility

After providing information, Dara always had the students working on an exercise in the problem worksheet. The format of the exercise was short answer questions and fill in the blank questions. The typical questions asked for information that the students could find in their textbook, handouts, and notes.

Dara believed that handouts and worksheets were the alternative way to support student's learning because they could practice and make sense of the concepts by completing the assignment. She did not correct students' work on the exercise, but rather asked them to study for themselves on the key sheet. Even though for some topics she had the opportunity to correct student's work, only a few students' results were corrected, while others were not. She asked those students whose work had not been corrected to check it themselves against those that had already had been checked by the teacher. However, typically she always moved on to the next topic without clarifying what students were doing. Dara expressed her views on having students correcting their work themselves. As she said, "In doing the exercise, I did not give them the answer or correct them because it is so easy. They themselves can arrive at the correct answer by studying the notes they have taken." (2nd Interview: Dara, Sep 1st, 2008)

On the other hand, only one topic, that on ionic dissolving, did she gives the students the answer key when they were assigned to do the exercise. However by doing this activity, students had only a little time to do the assignment. Thus the majority of students had not done the assignment when the teacher gave them the answers. Students could only just copy the answer into their note books.

In summary, Dara always used lectures and demonstrations or expositions, so that controlled teaching dominated in her classroom. She focused more on content than on student processing of that content. Therefore the power and responsibility were primarily placed on the teacher as the authority to choose what and how the content was presented. The bulk of knowledge was transmitted from teacher to

students at a fast pace. As to the process of learning, that process tended to be passive, with students receiving the knowledge passively. The students used low level processing skills, such as imitating or remembering, to understand the material. Little responsibility was placed on the students concerning their own learning. A final emphasis in Dara teaching practice was rote memorization. Rote memorization often was mentioned as one main aspect to help students' learning. If students can remember a lot, they can learn and obtain a better understanding. The learning process required students to do the assignment with problems presented after she was completed teaching but without clearly establishing whether or not students had understood correctly.

Social Interactions in the Classroom

Opportunity to Interact Among Students

In Dara's lesson plan, she had grouped students in clusters of four to five, in accordance with a group of learning strategies that she called number-headed together technique, which she drew from documents of her fellow teachers in her school. Number-headed together technique is a cooperative learning strategy that holds each student accountable for learning the material in order to promote student participation, learning, and understanding. Students are placed in groups and each person is given a number (from one to the maximum number in each group). The teacher poses a question and students "put their heads together" to figure out the answer. The teacher calls a specific number to respond as spokesperson for the group. By having students work together in a group, this strategy ensures that each member knows the answer to problems posed or questions asked by the teacher. In contrast to the ideal of number-headed together technique, in Dara's classroom, students were put into groups in a room in which the teacher rarely promoted cooperative learning. She had students learn by themselves through self-study from the instructional material provided to the group. Students were assigned to work alone. It was revealed that Dara had less understanding of a cooperative learning strategy, even though she had addressed that technique in her lesson plans. Students were put into groups, with no evidence of cooperative learning taking place.

When Dara implemented her plan, students were always assigned to work individually. The classroom interaction was limited because student interaction was basically confined to responding to teacher-directed questions. When Dara was asked for the reason why she wrote about the technique the number-headed together in her lesson plans but she actually did not adopt this technique into practice. She explained that she herself did not really understand how to implement that technique in real situations. She just studied that technique from her fellow teachers and then wrote the lesson plans. The written lesson plans were applied for teacher incentive or teacher reward.

The Teacher Awareness of Group Work

Even though Dara did not organize group work for student to engage in, the group dynamic emerged anyway in the attempt by students to complete their work. During one classroom observation on the topic of naming and formula writing of ionic compounds, an informal group consisting of four students was working right in front of me. They had handouts to read and work sheets they were required to complete. During this process, they were asking each other such questions as: "How can you name the compound formed from Aluminum and Phosphorus?" "What is the representative symbol for Aluminum?" "How do we label Phosphorus?" And "Am I right to read P as Phosphide? With each question, the students engaged in a dialogue that eventually lead them to collectively solve the problems presented. (1^{st} classroom observation: Dara, Aug 29^{th}, 2008)

In addition, the group dynamic not only emerged in this group; there was also dialogue among students in both intra and inter group teams. Some students initially tried to do the exercise themselves as individuals, and later did it with their friends who they believed were experts, with the result that there was some dialogue among them as to sharing what they were thinking and thereby furthering everyone's understanding.

Even though some evidence emerged that students were attempting to work cooperatively, Dara never mentioned this in our interviews or discussions. She instead described the learning center as the way for students to do self-study. In addition, Dara never explained how to assess the effectiveness of the learning center as group work.

Learning Assessment

Learning assessment in Dara's classroom typically included observation, assignments and worksheets, and tests.

The Use of Observation

Technically, in her plan, Dara sought to use observation to assess student group discussion and group participation. But she made practically no observations to assess student group participation in doing assignments or experiments because she did not provide any group work in any of her lessons. Group observation was replaced by classroom observation, in that she monitored how students were working on their tasks and she also assessed students' conceptual understandings. The results of observation were used to control or stimulate students to work in case they did not pay attention. She gave more attention to those who were working with incomplete understanding. In terms of assessing science process skills, only measuring skills were observed when she asked students to conduct an experiment. Those dimensions of student learning such as attitudes or social aspects were not emphasized or mentioned.

The Use of Assignments and Worksheets

Even though Dara expected the students to learn scientific knowledge, the methods of assessment she employed were not consistent with her intended learning outcomes. She used assignments and students' answers in worksheets to assess students' conceptual understanding, but rarely made corrections or gave any feedback

to students to develop any sense of progression in student learning. Students' work was checked only for classroom participation. In addition, the assessment tools she employed were not consistent with her intended learning outcomes. For example in teaching energy of ionic formation, the aims of learning she planned were that students should be able to indicate the released energy process or absorbed energy process of ionic formation, to write up the steps of ionic formation, and to sum up the net energy of ionic formation. In practice, she had students write up the process of sodium fluoride formation by rearranging the steps presented and then had them simply sum up the net energy of ionic formation. The only change from the example she provided earlier with NaCl was that the students simply substituted F for Cl. Thus, students only had to imitate the process she provided earlier and she did not ask the students to explain the process of ionic formation.

When asked in her interview after her teaching about students' understanding of the concept of ionic formation, Dara claimed that the students understood the concept of ionic formation quite well as she checked their work and they all were able to rearrange the steps of ionic formation correctly and were also able to sum the net energy used for ionic formation. When further asked about students' understanding on other aspects addressed in her learning aims she replied:

> I did not ask further questions to extend students' understanding of each step of ionic formation. Thus, I did not know whether students understand the concept. I think that to discover students' understanding I will probably test them or ask them later to explain these concepts next time." (2nd Interview: Dara, Sep 1st, 2008)

As the comment above indicates, even though she focused largely on student conceptual understanding, this assessment method was not fulfilling her goal of teaching students the key concepts since the assignment did not examine some key aspects. In addition when asked, she was uncertain as to whether students answers to questions on their tasks could give her information of students' conceptual understanding, since students always simply copied the assignment.

The Use of Tests

While I did not observe Dara using tests to assess student's conceptual understanding, she always mentioned her use of tests many times during our interviews. She mentioned her use tests because she thought that other methods such as asking questions, observation, or even student work could not give her much information about student's understanding. In her lesson plan the test was designed and planned to assess student's conceptual understanding before and after learning each topic. The formats of the test were multiple choice and fill-in-the blank questions.

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

Teacher's Roles

Regarding the teacher's role, Dara played various roles in her classroom, typically including that of information provider, resource developer, and learning assessor.

The Information Provider

Dara used interactive ways, including the lecture and explanation, to pass information to the students. She taught with a direct focus on the transmission of subject matter. Students who acted as receivers were always asked to memorize and copy information given by the teacher. She always made the decisions and decided what she wanted students to learn. When teaching, she initially explained the content knowledge and then asked students to copy what she had explained and written on the

blackboard. Following her explanation, she had students do the assignments. Handouts and work sheets were distributed to students, or problem questions were written on the blackboard. Students were allowed to work on the assignments, and they sometimes had to stop work on their assignments if the teacher moved to the next topic. Students' answers were not checked for correctness and clarified by the teacher. On the contrary, she checked whether or not the students' work followed her direction. The example below illustrates some of these points.

Before explaining to the class how to write the ionic equation, Dara wrote one un-balanced chemical equation of oxygen gas and hydrogen gas to get a water molecule, as an example leading to a discussion on how to balance a chemical equation: "What product is produced from reacting oxygen gas and hydrogen gas?; How do you balance this equation?; What number do you place in front of hydrogen gas and oxygen gas?" She then discussed a reaction learned in a previous class, a reaction between calcium hydroxide and sodium carbonate to get calcium carbonate, and showed the class how to balance the equation. She gave a mnemonic code to remember, and some students recited after her without understanding exactly what she had said. However she did not clarify the meaning or reason for using such a code. Then she asked students to write and balance the molecular ionic equation for calcium hydroxide and sodium carbonate to get calcium carbonate. She summarized what she had explained about the ionic molecular equation, and indicated what she was going to teach. Before finishing the class, she had students correctly copy everything written on the blackboard and had students ask questions in case they did not understand. Dara during an interview described her use of lectures and of giving students information by commenting:

> I taught by first using a lecture to give students information in order to guide them in what they should know. If I had them study on their own by reading the document and doing the exercise by themselves without any help from me, the whole process, they would probable get confused. In addition, to support student's learning, I gave them the document sheet and had them practice by doing the exercise." (4th Interview: Dara, Sep 12th, 2008)

The Resource Developer

Another role that Dara acted out was that of resource developer to create new learning environments. The instructional package developed by Dara was used instead of using a textbook to which the students had access, and made it much easier for them to take more responsibility for their own learning. The instructional package mentioned by Dara consisted of handouts, worksheet, key, and some figures. The instructional materials were distributed to students when they were asked to do the exercise. Dara described the use of the instructional package thus:

> It is a tool to help students reach an understanding of the topic. Because students have a short concentration span, they don't listen when I am writing (on the blackboard) and explaining. But if they study from the handout and see the example provided, coupled with doing the exercise, they all eventually can do the exercise successfully. Furthermore they claimed that they cannot see the blackboard. Thus using the instructional package can help them to study. (2nd Interview, Dara, Sep 1st, 2008)

The other resource material used to support students' learning was in card format in the form of a game. The cards contain an element symbol, the name of elements, a chemical formula, and the name of a chemical formula. The card game was developed to help students remember the symbol of the element and make them familiar with the name of the ionic compound in a more engaging atmosphere. After learning about naming ionic compounds, students were engaged in the card game. The teacher first explained the game rules and then played the game with students in order to encourage them to participate in this activity.

During classroom observation, some students actively engaged with each other, as they were playing the game. Even though some students remained unengaged in the game in the first round, they still watched others who were playing and then asked to play for the second round. At one point, Dara asked one female student to explain the rules for a new player. She could explain to her friends and gave

examples correctly. In addition to promoting students' learning, Dara also explained that the game itself in class time was not the end of the activity. Students could ask to borrow a card game set to play a game outside of class time.

Even though Dara was a developer of instructional materials such as the card game used for encouraging student to participate in the learning process, with respect to the other instructional materials such as the instructional package, Dara continued to use traditional paper media that reproduced instructional material and handouts on the topics that were already covered in books or other resources.

The Learning Assessor

The assessment of the students' competence was one task facing the teacher. As an assessor Dara had the role of passing judgment on the students. She described her way in assessing student learning that she mainly emphasized on student's conceptual understanding. In my observations of her teaching practice, she was the only one who checked students' understanding when they answered her questions and did the assignments. However when talking about her role as assessor of students' learning, she herself could not evaluate how students' conceptual understanding improved, since students always copied work from their peers. Students handed in their group work individually but she was unable to monitor whether students were copying their friends' work. Consequently she gave them equal scores and did not use the assessment to further the learning process.

Summary

In summary, in Dara's classroom, knowledge primarily came from the teacher. The teacher was the major source of information and an information provider. She used her expertise in content knowledge to help students make connections, usually by means of the teacher talking and students listening. When planning the lesson, Dara acted as planner as well as decision maker for what and how of the learning process. The effort to get to know the students and to understand how they processed

information was secondary. To facilitate a student's learning, Dara acted as resource developer to produce instructional materials, but some materials just only repeated what was already covered in text books. As regards learning assessments, Dara always monitored and corrected students' answers and their works. But she neglected to correct the work of some students, which left them in some confusion. In her classroom, only the teacher acted as assessor to evaluate student learning, but her assessment methods did not appear to support her objective of promoting increased student understanding.

The Case of Aree

Aree's Background in Relation to the Constructivist Teaching Approach

Mrs. Aree had no experience of studying or attending workshops that directly focused on a constructivist teaching approach. However she had studied the related documents based on cooperative learning, such as learning through jigsaw technique, and had studied inquiry learning (5E) from documents mainly published by the Institute for the Promotion of Teaching Science and Technology. She personally viewed the constructivist teaching approach as one in which students played an active role in their learning process. Aree claimed that students constructed understandings through searching for information and through hands-on activities. To complement the student's learning process, the teacher had to provide explanations to students to help them construct their understandings of the subject matter. However, with this approach Aree believed the teacher was not an instructor who taught alone in the classroom; rather, students were to be encouraged to get involved in their own learning activity.

In Aree's opinion, there were limitations to using the constructivist approach in her classroom. Firstly, it was time consuming, because more time was needed to ask students questions, to wait for a student's response, or to monitor the construction of each student's understanding, etc. Secondly, she had to cover all content framed for her course, and that did not allow her to use the constructivist approach in her classroom.

Thirdly, some students needed more information and preferred to be passive learners, and absorb information purely for use on examinations.

Aree's Teaching Practice

In this section, the results of Aree's practice in terms of the activities in her class are discussed. The data were collected and teaching practices were observed in one classroom of 10th grade students who were studying in the science program. The instructional unit observed was ionic bond, including four main concepts: ionic bond, ionic compounds: naming and formula writing, solubility of ionic salts, and covalent network structures and metallic bond.

Lesson Introduction

The Realization of Students' Prior Knowledge

During the first few introductory minutes of the lesson, Aree reviewed previous knowledge to help students see the logical flow and continuity of content. She announced the lesson's topic and then reviewed previous knowledge, such as the term ionization energy [IE] and the term electronegativity [EN], so as to inform students whether or not they had the proper prior knowledge needed to acquire the new material. Ionization energy referred to the energy required to remove the outermost electron in the atom or molecule when the gas atom or molecule was isolated in free space and was in its ground electronic state. Electronegativity referred to a chemical property that described the ability of an atom to attract electrons toward it. She explained all these chemical terms before teaching the concept of ionic bonding.

> Prior to teaching, I ask them about the previous knowledge which relates to the current concept being taught. For instance, in teaching the ionic bond, I ask about IE EN. They have to know about these concepts and I want to know how they understand these concepts and then relate these concepts to the current concept being learned. (1st Interview: Aree, Aug 5th, 2008)

In every classroom observation, Aree typically reviewed the students' previous knowledge, and provided students with a clear sense of the day's topics and their relation to the course as a whole. She assisted students to recall the past material and previous knowledge, using questioning on the problem presented. Students were allowed to discuss both as individuals and as a group, and eventually Aree gave the students sufficient explanation to fill in the content knowledge that was needed to understand the current concept.

For example, before teaching ionic naming and formula writing, Aree reviewed for students the concept of ionic bonding, using questioning and explanations about the ratio of ions forming the bond. In another example, Aree asked students one by one some questions and had them explain the hydrogen bond before learning about the covalent network and metallic bond.

Aree not only asked for the previous knowledge used for the new concept but also for the students' prior knowledge as to how they understood the new concept before being taught it. Before teaching the ionic bond Aree reviewed and asked about states of matter and their physical properties, such as melting point and boiling point. The aim of this discussion was to elicit students' prior knowledge about the chemical bond and enable students to get a sense that there were forces of inter-molecular attraction and intra-molecular attraction. She then introduced the force in terms of chemical bonds that hold atoms together in a molecule and ions in ionic compounds. Regarding why chemical bonds formed, she also used questioning to review students' previous knowledge about the arrangement of valence electrons that makes an unreactive atom, and then eventually discussed how these atoms form a bond. Questions were asked such as: What group in the periodic table is very unreactive?; What do all noble gases have in common? (They all have 8 valence electrons); What rule is used to predict whether an atom is very unreactive? (The octet rule)

Even though in some topics, as above, Aree asked students about their prior knowledge of the topic that they were going to study, her practice was not consistent. Aree remained confused about, or had incomplete understanding of,

eliciting prior knowledge. For example, she was going to teach about ionic compound properties which focused on ionic salts solubility. To elicit students' prior knowledge, the teacher might ask what they know about ionic solubility, or what they know about ionic properties. On the contrary, Aree asked her students about how ionic bonds formed which was less related to the topic she was going to teach. In addition she did not use such questions to introduce the new concept. The questions Aree got students to focus on when eliciting students' prior knowledge were focused only on what the answer was about, but not related to her purpose for teaching. In addition, she always placed much emphasis on reviewing the previous lesson to help students remember information.

Learning Activity

In an attempt to facilitate the learning activity for students, Aree used a questioning technique during teacher's explanation, hands-on activity, and exercise with the interactive handouts.

The Use of Questioning

Aree often used explanation to provide the key concepts of a particular topic, and emphasized core subjects existing in books. Handouts and worksheets drawn up by the teacher were distributed to students before teaching. She followed up by asking students questions and then provided explanations. She shaped the learning activities to encourage students to take an active part in learning the material. She incorporated into her explanation opportunities for students to ask and answer questions, participate in brief discussions, and solve problems.

She took time at the beginning of the class to ask questions in order to connect the day's ideas, concepts, or problems to material that she had presented in the previous class and to the overarching themes of the course. Before introducing a new concept she used questioning to assess prior knowledge or previous knowledge needed for the new concept and to clarify a vague comment. During teaching she used

questioning and students' explanations of the concept in order to assess student learning. When asking questions, she gave students 1-2 minutes to think and formulate a response. If time passed without anyone volunteering an answer, she rephrased her question. She always asked the same students follow-up questions to prompt students to clarify, refine, and support their ideas. When a student gave an incorrect or ill-conceived answer, she responded in way that challenged the student to think more deeply or to reconsider the evidence. Finally, she pointed out what was incorrect about the answer and filled in the necessary points to complete the answer.

For example, when teaching about the ionic bond, Aree used questions to encourage students and asked follow-up questions after students got a sense that there was a force of inter-molecular attraction involved. The teacher introduced the force in terms of chemical bonds and explained today's lesson on the ionic bond. As to the reason why chemical bonds form, the teacher explained and had students view the handouts simultaneously.

She began by asking questions as to what students had learned in the previous instructional unit. Various questions were used including: In forming a compound, what electron arrangement takes place? What group in the periodic table is very unreactive? How many valence electrons are there?

After students arrived at the octet rule of unreactivity, she continued asking students in order to explain how the ionic bond is formed, using the following questions: What is the nature of valence electrons of elements which have low ionization energy? Which groups of element have low ionization energy? Which group has the lowest ionization energy among group one, two, or three? Why does group one have the lowest ionization energy when compared to group three? How about atom size? Among V, VI, and VII groups, which group has the highest ionization energy? How about electronegativity of VII group? The teacher discussed with students how an ionic bond was formed, kept questioning, and explained that an ionic bond was formed by the transfer of electrons, producing ionic compounds.

In terms of the concept of learning, she not only focused more on content but also on student processing of it as well. Student understanding came from the teacher's explanation and student's response. The process of teaching and learning tended to be active, with students engaged as active listeners while participating in the teacher's explanation and responding to the teacher's questioning.

The Opportunity to Do Hands-On Activity

Even though the teacher acted as the major information provider, with the power and responsibility being primarily placed on her, there were times however when student knowledge was arrived at through the combined efforts of both teacher and students. While the construction of the students' knowledge was under the guidance of the teacher, the students synthesized the gathered information using problem solving, critical thinking, and inquiry skills.

Additionally, in her view, student classroom participation and hands-on activity were important characteristics of good teaching. She expressed her ideas about her teaching, in which students took roles and participated in learning activities. The students had a chance to do experiments instead of simply being given content knowledge by the teacher. She felt they should do activities, think, present their ideas, exchange their ideas with their peers, and react to things around them. With regard to letting students do hands-on activity, Aree said:

> It's nice to see them enjoying themselves. Inspired by hands-on activity they can really interact with instruments and do the work on their own. After they have learned the concept, they then have the opportunity to do hands-on activities and let their minds grow. They can learn by conducting the experiment. They can get the knowledge based on the experiences and the environment they are exposed to. For example, I have taught them that if the temperature is increase that means the process is exothermic; on the other hand if the temperature is down, that means the process is endothermic. As I observe them doing the experiment, they

> can accomplish the main objective of the experiment properly. (2nd Interview: Aree, Aug 26th, 2008)

Aree thought that there needed to be a bit more teacher direction in order to do the experiment correctly. Because of students' lack of experimental skills she thought she should give more scaffolding. She produced handouts which students were able to follow in cookbook style and thereby produce the expected results. By this approach, students completed activities designed by the teacher to achieve goals determined by the teacher. During the one session of classroom observation, Aree provided students with a written description of their task, and students were assigned to work within teacher-selected groups of seven students.

In this experiment involving the dissolving of an ionic compound, she told student to study the effect of changing temperature on the amount of ionic compound that would dissolve in a given amount of water. The teacher then explained lab procedure:

> In this experiment, you will completely dissolve different quantities of potassium nitrate, KNO_3, sodium chloride, NaCl, ammonium chloride, NH_4Cl, in the same volume of water. As each solution is dissolving, you will monitor the temperature change using a thermometer. Thus each data pair consists of an initial temperature and a resulting temperature (in ^oC). (2nd Classroom observation, Aree, Aug 26th, 2008)

She had the students look at the lab procedure in the handout provided for setting up the equipment and performing the experiment. She then gave a list of equipment that was used to perform the experiment, including a calorimeter used to contain the solution. However she did not discuss how and why a calorimeter was used. She had students take note of the initial temperature as well as the final temperature when the dissolving was finished. After she explained lab procedure, she allowed students to do the experiment without any discussion about identifying and controlling

variables. After students had done their experiment, she asked them to present their findings and conclusion to the class.

Even though the students used high level thinking skills such as analyzing or synthesizing to understand the material, much responsibility still remained on the teacher to pose the problem of the experiment as well as to detail the experimental procedure. On the other hand, less responsibility was placed on the students concerning their own learning, as they were only being asked to do the experiment.

The Ways in Doing an Assignment

She used writing assignments during the class to prompt student thinking about the key concept. Students were allowed to work on the written assignments through informal small-groups. In every single session of observation, and as the teacher confirmed in interviews, interactive handouts and worksheets were given out during the teaching to help students and support the lesson by giving the students practice on key concepts. These handouts had activities or problems for the students to perform. The format of the worksheet consisted of short answer questions, containing ten to fifteen items. Aree always said that if students had more opportunity to practice they would gain better understanding. After having finished explaining the content knowledge or any additional information, Aree had students answer the questions presented in the worksheet, and after everybody had finished the assignment, she asked students at random to share their answers. When the selected students had given their answers, other students considered whether they were right. In case they were not, the students could respond with an argument. Then the teacher wrapped up the discussion.

Social Interaction in Classroom

The Group Work in Classroom

Aree incorporated group work into her classroom procedure. Aree primarily planned to group students in clusters of four to five students, but in practice students were not organized as expected because the physical environment was not adequate for smaller groups. Therefore the larger group size was organized which contained seven to eight students, and which made it more difficult for Aree to conduct the lesson. In Aree's classroom, cooperative learning was promoted by allowing the students sufficient positive interdependence to share their ideas together, while each group member remained responsible for his or her own work. Aree described ways that groups can be used in the class:

> Students are divided into six groups depending on tables available. However, while they are working on tasks, some of them go to other classmates who are close friends. An example of using group work is in doing an experiment, wherein all members have to work together and hand in to the teacher only one report. On the other hand I observed how students worked in their group; for example, when they did an assignment about chemical bonding, I found that there was some dialogue, which they were thinking and sharing with the others. For instance, one student asked their friends what this type of bond should be. It was a similar situation with another group sitting at the back of the class; they discussed and shared together. (4th Interview: Aree, Sep 9th, 2008)

In classroom observations, the group dynamic emerged in many ways. One example occurred when students were working on their task of drawing the ionic bond of various compounds. The female group was working in front of the researcher. There was dialogue among them, for instance: "What is the atomic number of Sodium"; "The bond written is a single bond, not a double bond"; "Writing two dots represents one single bond, doesn't it?" With this conversation they were able to collectively solve the problem presented.

The group dynamic emerged in the classroom freely, and for the most part each member of a group was willing to work with other member of that group. However, there were some instances where some students worked individually. The group work did not explicitly set the stage for students to learn social skills. Leadership, decision making, and trust-building remained unsupported by the teacher. On the other hand only communication skills were developed to any extent in cooperative learning when the students had the opportunity to do actual group tasks such as experiments.

In general Aree did not provide students with clear learning objectives or lay out a design of group work, nor ways of assessing work, nor agreement on how the group would be monitored. The failure to provide clear objectives caused some students to remain working on their tasks individually.

Due to group work, how groups were functioning was reviewed only by the teacher. The teacher got no chance to discuss special needs or problems within the group. On the other hand, the groups had no chance to express their feelings about beneficial and unhelpful aspects of the group learning process in order to correct unwanted behavior and celebrate successful outcomes in the group work.

Learning Assessment

The Use of Observation

Even though Aree did not directly admit to using observation as a form of learning assessment, my classroom observations revealed that she incorporated observation as one assessment method as a daily routine of interaction with students. During one observation, she had students study the naming of ionic compounds. Although students had to present their answers to the class to show that they understood, Aree was confident that the real learning took place in the process of working with the students, and she continually interacted with each group to assess their understanding. While students were working on their tasks, she rotated from

group to group. When they wrote ionic formulas and formula ratios between cations and anions of ionic compound, they asked the teacher some questions, as indicated in the dialogue below.

Student: What is the ratio? What does it mean?

Aree: For example, this aluminum nitrate compound. It is formed by the bonding of the aluminum ion (Al^{3+}) and nitrate ion (NO_3^-). The ratio is 1:3. It means the ratio between mole number of cation and anion to form a compound.

(2^{nd} Classroom observation, Aree, Aug 18^{th}, 2008)

The teacher then walked to another group and asked them questions. After walking around the room to all groups, she found that students got confused about the ratio between cation and anion in each compound, and how to write the number of the prefix as a subscript of the element. She used the feedback from observations and then went back to the front of the class and explained how to write ionic formulas again.

As indicated above, Aree assessed students' learning in terms of formative assessment including questioning and observation, with classroom instruction. The formative assessments were used to monitor and to diagnose learning problems, which she could then use to shape her teaching to encourage better learning.

The Use of Assignment and Worksheet

She used writing assignments during the class to prompt student thinking about the key concept, and to assess how students understood the key concept as well.

Aree provided students with learning problems in the form of guided tasks, from which students could learn the example or way to answer in the handouts provided. After she had asked students to do the assignment, she allowed about 10- 20

minutes, which was enough time for students to answer questions or complete tasks and exercises. The students did their work initially working individually, and later discussed their work together in small groups. Student work was corrected by using the whole class discussion. Aree typically invited her students to share their working experience in the class discussion. She considered this an opportunity to discover what the student really knew. She describes:

> I had them draw the diagram of ionic bond forming on the blackboard and then explain the process of bond forming to the class. Even though they did not explain smoothly and used their own language, this revealed that they understood how an ionic compound formed. (1st Interview: Aree, Aug 5th, 2008)

The assignment was one of the learning assessment methods that Aree used for diagnosing student's conceptual understanding.

The Use of Quizzes

Aree's teaching practice followed a distinct step by step procedure. She used multiple choice tests as her main assessment tool. Once the subject was taught, assessment followed. Aree saw assessment as a necessary component of teaching. She made use of the quizzes developed by the chemistry textbook and applied them to her classroom. She typically included her quizzes at the end of every topic. The format of Aree's quizzes was primarily traditional multiple choice, containing five items. When she had administered the quizzes, she immediately checked their answers to inform students how much they had scored. Aree said that her quizzes were an indicator to her as well as to her students of just how well students had learned the material. Students who gained a low score would use the result of the quizzes to jolt themselves into changing their behavior and studying harder for the next concept. The results of the tests were recorded, and the function of the assessment was to monitor the academic progress of the students.

Teacher Roles

As a classroom teacher, Aree played various roles in facilitation of student learning.

The Information Provider

Aree believed that it was the responsibility of the teacher to pass on the information and understanding of a topic to students. In providing the information, she assisted the student in interpreting it by using one of a variety of educational strategies by which she explained or asked about the subject matter. She always used the printed material and sometime used PowerPoint as instructional materials for providing new information. In describing her role as a provider of information to the students on the topic of ionic bonding, Aree expressed herself as follows:

> For today's topic [ionic bonding] I actually used printed material, both handouts and worksheets, to have students study themselves and then practice on the worksheets. What I found was that if I allowed them to learn by themselves it certainly was not effective. Thus I changed the way from having them learn by themselves to explaining the subject matter for them coupled with questioning. In general the way I teach is to provide the information by explanation, and supplement this with asking questions" (1st Interview: Aree, Aug 5th, 2008)

One example from classroom observation of Aree's coverage of the naming of ionic compounds illustrates how she provided information. The teacher distributed a hand-out presenting the rule for naming and writing ionic formulas. She introduced students to today's topic and gave them the necessary information about naming ionic compounds. She initially introduced how to name cation and anion as single ions, and then introduced di-atomic and polyatomic ions of both cations and anions. While giving out this information she had students view the handouts and answer such questions as: Which ion always comes first in the compound? What is the

end sound of ionic compounds? What do you call NaCl? In the mean time, the teacher wrote the formula as an example of an ionic compound, showing the combinations of ions formed into compounds and the ratio between cation and anion of the compound. She further explained how to write ionic formulas and had students view the handouts and worksheets which showed students how to write ionic formulas and which gave the naming of different ionic formulas. Students then worked through the questions on the worksheet. Finally she had students present their answers to the class. After students presented their answers, she filled in the gaps by giving more explanation of any of the missing points.

The Learning Planner

In order to organize learning activity, Aree had planned her lesson as a daily lesson plan. Regarding the school curriculum, Aree planned her lesson so as to cover the content required for her students' grad level. In her lesson plan, there were various issues addressed, including: the expected learning outcome, the main concept, the learning activities, the assessment methods and tools, and the instructional materials. She described her procedure in planning a lesson as follows:

> As I got the suggestion from the supervisor that teaching should be based on the science learning standard, I then put the learning standard into my lesson plan. I later analyzed the learning standard to set out the expected learning outcome. After I got the expected learning outcome, I set out the main concepts being taught and the method of teaching them. I relied on the subject matter in the textbook published by IPST. In addition, I also added more information, using textbooks from various publishers. The material used in class was based on the handouts and worksheets adopted from the chemistry textbooks, and on Power Point presentations downloaded from internet. (4th Interview: Aree, Sep 9th, 2008)

Aree also knew how to adopt the material available, such as Power Point presentations, to support learning by providing information on the topic of study. These

Power Point presentations were prepared by curriculum developers and distributed to teachers. She described her opinion on using Power Point thus:

> I actually would like to draw a picture on the blackboard and then give an explanation step by step. But using Power Point as a tool to see the picture is easier and clearer. It also helps me to keep teaching without losing too much time. Even though I am not a resource developer of this Power Point, I find and adopt the material available as a tool for me and use it to help the students understand the picture much faster. (4th Interview: Aree, Sep 9th, 2008)

The Learning Facilitator

The teacher's role was not only to inform the students but to encourage them to learn for themselves, using the problem as a focus for learning. Aree communicated with students in an informal way in the small group sessions, and encouraged students to learn by creating an atmosphere in which open exchange of ideas was facilitated. In classroom observations, one example occurred when Aree interacted with students in a classroom discussion.

After presentation and explanation of the covalent network structure and metallic bond concept, the teacher had students answering the questions as individual work, but students could share their work with other members in a group. After everybody had done the assignment, she switched their answer sheets and called on one student who was willing to share her answers. While the girl gave her answer, others considered whether the answer was right; in case they thought it was not right, they could make an argument. Finally Aree wrapped up, giving the answer again. As is evident below, Aree facilitated student learning while interacting with them during a discussion of their assignment:

Student: Regarding ionic compounds, they are found in three states.

Aree: In general ionic compounds are found in a solid state. (Aree revised student answer.)

Student: The lattice particle is found in a solid state. (The student revised her answer and continuing to give other answers.)

Aree: What about metal? (Aree nod to agree with the girl's answer and then she asks a question.)

Student: Metals are found in a solid state.

Another student argues: What about mercury? It is liquid, isn't it?

Student: Okay it is liquid.

Aree: Thus, how many states are metals in?

Student: They are in solid and liquid states.

(4th Classroom observation: Aree, Sep 9th, 2008)

Aree kept up her interaction with students, helped them to revise and complete their answers, opened her mind to listen to other answers from students, and eventually encouraged them to arrive at conclusions about the relationship between matter properties, including states of matter, solubility, electricity, and ability to dissolve in various types of solvent.

She not only facilitated student discussion, but also provided the students with opportunities for working in the learning context. She also continued observing the students and giving feedback. When students were working on their tasks, Aree always walked around and helped students one by one if they had problems.

The Learning Assessor

The assessment of the student's competence was one of the most important tasks facing the teacher. As an assessor, Aree had the role of passing judgment on the students. Aree explained her role in assessing student learning in terms of various purposes:

> The quiz is an objective assessment, one that is based on criteria that I myself and the students recognize and accept. Those who gain a score of more than fifty percent of the quiz pass the quiz. Other assessments such as student

attention at work, or student performance of an experiment, for those I actually created the assessment tools to assess the student's practice. But it is time-consuming. What I generally do is use observation by myself to measure how they work. From the results of assessments such as quizzes I am able to identify and inform them of strengths and weaknesses in their understanding. As a result of hearing such information, students can shape their practices to pay more attention to certain areas in case they have gained a low score in those areas. On the other hand, those who have gained a high score will have more confidence about and enthusiasm in their learning. (4th Interview, Aree, Sep 9th, 2008)

Summary

In summary, in Aree's classroom, understanding came both from the teacher and from students' participation in the activities provided. Even though the teacher acted as the major information provider, sometimes the understanding was the product of the combined efforts of the teacher and the students. Under the guidance of the teacher, when doing tasks, students had an opportunity to talk without constant teacher monitoring. Aree acted as facilitator to provide feedback or correction when questions from students arose. As regards learning assessment, Aree fulfilled her role as an assessor who evaluated student learning in all domains.

The Case of Benja

Benja's Background in Relation to the Constructivist Teaching Approach

Based on her experience as a participant in a constructivist workshop which provided her with some information and examples that had made a great impression on the constructivist approach, she believed that in teaching based on the constructivist approach students had to learn by seeking to construct their own body of knowledge themselves, without any scaffolding from the teacher at all. But using this strategy depends on the learning activity being simple. Complicated or difficulty activities would not be able to apply this strategy to help students construct a body of knowledge.

This view meant that Mrs. Benja did not believe that the constructivist approach could be applied to the teaching of chemistry, because of its difficult subject matter.

She decided to participate in the collaborative action research project because she wanted to learn about various good teaching methods that could be applied in her classroom. It could enable her students to learn analytical thinking. She also wanted to learn the various teaching methods that are most fit for her student's capabilities. Due to her professional development, she would like to develop her teaching practice by incorporating what she gained from the present project into the cooperative learning technique that she already knew. In addition she would like to develop a better understanding of the constructivist teaching approach.

In Benja's opinion, there are limitations to using the constructivist approach in her classroom. Firstly, the fact that it is time consuming does not allow her to teach the constructivist approach in her classroom, since she has to cover all content framed for her course in a certain time. Secondly, some students need more information and they do prefer to be passive learners to get sufficient information for the examination.

Benja's Teaching Practice

In this section, Benja's practice is examined through the various activities in her class. The data were collected and teaching practices observed in one classroom of 11^{th} grade students who were studying in the science program. The instructional unit observed was stoichiometry, including four main concepts: calculation of chemical formula, chemical equation, substance mass of chemical reaction, and gas volume of chemical reaction.

Lesson Introduction

The Realization of Students' Prior Knowledge

Before teaching a new concept, Benja posed a main question to the class to think about with regard to the previous concept learned. She then asked a series of questions to assess students' understandings, and as well addressed the weak points of the students by explaining to students the previous concept needed for studying the new concept. Next she asked one or two questions to help students grasp what they already knew about the new concept and, as well, to assess students' understandings about the new concept. Benja asked students to share their ideas before moving on to learning activities. She also provided students with some feedback to help them assess their current level of understanding. This feedback also helped students shape or re-shape their understandings.

For example before teaching about chemical equations, Benja gave one example by writing the symbols of the substances reacted, which were oxygen gas ($O_{2(g)}$) and metal solid of magnesium ($Mg_{(s)}$), and the substance produced which was magnesium oxide ($MgO_{(s)}$). Then she asked questions to elicit students' prior knowledge and related that to the current concept, as the dialogue below shows:

Benja: Let's consider the reaction between oxygen gas ($O_{2\ (g)}$) and metal solid of magnesium ($Mg_{(s)}$) to generate magnesium oxide ($MgO_{(s)}$). The example presented is called the chemical equation. Tom, what do we know from the equation presented?

Tom: (Quiet)

Benja: Okay Tom cannot answer. Dan can you answer me?

Dan: It gives the information that the solid reactant reacts with the gas reactant.

Benja: What is solid?

Dan: Magnesium.

Benja: What is produced from this reaction? (Teacher asked other students.)

Students: Solid.

Benja: What is its name?

Students: Magnesium oxide.

Benja: What do we call whatever we get from the reaction?

Students: Product.

Benja: You have known about reactions. What about the ratio of the substance reacted to form a compound? Considering this equation, if two moles of magnesium react with oxygen gas, how much oxygen gas is required?

Students: Two moles.

Benja: Two moles atom of oxygen but one mole molecule of oxygen gas, you have to be clear.

(1st Classroom observation: Benja, Jul 30th, 2008)

Benja then related student's prior knowledge to the new conception by stating:

> In writing chemical equations we have to indicate the mole of each substance (reacted equivalent?). On the other hand what do you think the ratio is in terms of mass (in gram units) or of volume. Can we indicate the ratio of each substance in terms of mass or volume? Today we will proceed by conducting an experiment to find the volume of reactant [reacted equivalent?] and then use this result to write up a chemical equation. (1st Classroom observation: Benja, Jul 30th, 2008)

However Benja always used questions and class discussion as a way to uncover students' prior knowledge. Questions were asked of some students randomly, in order to assess their prior knowledge. By using this technique Benja could not really know what other students, who were not asked, knew about the current concept.

Learning Activity

Benja believed that learning happens when students were actively involved. Her teaching practice emphasized attempting to facilitate the learning process for students. Benja used questioning and hands-on activity.

The Use of Questioning

A main method of Benja's instructional practice was questioning to engage her students. During every classroom observation, Benja started the class by posing the problem in order to prompt students to discuss the previous concept, and then related that concept to the current concept. For example, before teaching about the ratio of gas in terms of volume in any reaction, she asked students to compare it with the ratio of other substances in term of mass, which had been learned in the previous class, and whether or not it obeyed the law of conservation of mass and the law of constant proportion. In addition, when teaching, she always stayed with the student until the student was able to answer the question correctly or understand the concept clearly.

For example, when she described the use of questioning as helping to conclude the experimental result of the study of the reaction between lead (II) nitrate and potassium iodide, she said: :

> For today it was so slow because the fact that the experimental result was in error created problems for the conclusion. However I managed to keep the learning activity going. I asked them a lot of questions in order to help them arrive at a conclusion. I used questions to help them see what the result really should be, and they eventually could explain and give reasons for the conclusion. (2nd Interview: Benja, Aug 1st, 2008)

She described the way she asked questions of students in her class, as well as the reason for using questioning:

> In general I primarily pose the questions and let them think about them. The discussion of the questions posed will be linked to the content being taught. When I teach I use explanations and encourage student to conclude the lesson together. I myself like this way of teaching. It encourages thinking all the time. (1st Interview: Benja, Jul 30th, 2008)

In addition she described encouraging student critical thinking and inquiry by asking them thoughtful, open-ended questions, and encouraged them to ask questions of each other as well as of their teacher. She not only encouraged students to respond to questioning, but also encouraged communication between the teacher and the students and also between the students themselves:

> When I use questioning or whatever, naturally students can answer either rightly or wrongly. I should address any weak points which remain as a result of their failure to understand. I always allow them to talk, but it is not nonsense talking. On the other hand I tell them: do not keep quiet when I am teaching. They should both question the teacher and answer the teacher's questions. If they have questions, I allow them to ask me immediately. (1st Interview: Benja, Aug 1st, 2008)

The Opportunity to Doing Hands-On Activity

In her classroom, Benja thought it was important to include hands-on activities to capture student interest and help students make sense of the material they were learning. She described how doing hands-on activity like the experiment could help students arrive at a better understanding: "What I can see is that they can explain the results of the experiment correctly; when I ask them for reasons, they can provide them to me." (2nd Interview: Benja, Aug 1st, 2008)

Typically when using hands-on activity, Benja started the lesson by reviewing the previous concept as a warm-up activity, asking students to explain the problem posed. For example, in order to write chemical equations, the students were prompted to think of the relationship in terms of mole of reactants and products

presented in each equation. After discussion, she came up with the conclusion that the simplest ratio of the number of moles of reactants and products in a chemical reaction was constant in the same reaction. She asked questions to prompt students to prove whether the other reactions presented relied on the constant ratio of the number of moles of reactants and products in the chemical equation. She told students what they were going to prove about the mole ratio of reactants. Students were asked to discuss how to design the experiment's procedure. Instead of asking students to write out the aim of the experiment, construct a hypothesis of the experiment, create variables of study, or write out the laboratory experiment before doing the experiment, she asked students to write it out later as part of their homework. After students had shared orally their ideas about their procedure, she immediately had them view the experimental procedure in the chemistry textbook. She explained the lab procedure and what was to be observed. Next, students were allowed to do the experiment. Because there was insufficient time to fully conclude the experiment, Benja had students record all data and asked them to discuss it during the next class. For the second time in this experiment, Benja asked each group to share their results by filling in a table which was to be used for class discussion. Before Benja led the class to make a conclusion on the results, she asked students for the aims of the experiment, the hypothesis, and the procedure. She justified asking about the aims of the experiment and the hypotheses after doing the experiment thus:

> When I teach I think that if somebody does not understand initially, I should lead them to do the experiment first. When they are finished, I will lead them to discuss the aims, hypotheses, and variables later, because when they have already done the experiment, they would know what is the hypothesis or variable because I discuss and explain with students about the aims, hypothesis and the conclusion before I ask them to write the report and hand it in to me. I purposely want them to write the report correctly, so that I do not have problems with their results and reports. On the other hand if I do not discuss with them and agree with their conclusions, I might have problems correcting their reports. (2nd Interview: Benja, Aug 1st, 2008)

As she described it, the problem with using a laboratory as part of the teaching practice in her class was that typically students arrived at the laboratory to do an experiment without a clear idea of the procedure, the problem of what they were studying, the aims of the experiment, the hypothesis, and the variables. Benja often discussed with students, after the laboratory and during the write up of the report, just what it was they had been doing in the experiment.

Social Interaction in Classroom

The Group Work in Classroom

Benja believed that cooperative learning worked best when group size was smaller. In her classroom, students were typically grouped in clusters of five students who sat at the same table. Benja encouraged face-to-face interaction within groups, in the form of encouraging, supporting, or assisting each other, in order to ensure the success of group members.

Typically, there were two group formats in Benja's classroom, depending on the purpose of the activity: informal learning groups and formal learning groups. Informal learning groups were initiated when Benja asked students to turn to a neighbor in the same group and spend a short time discussing a question she had posed. In some periods the informal groups were formed of three students to search for information in the textbook and to solve a problem posed. Benja always organized informal groups any time when discussing and having to do assignments.

On other hand the formal learning groups of five students were sometimes established to have students complete their tasks, including performing a lab experiment and writing a report. She described the way to organize students into groups that revealed what she considered necessary to organize student groups:

> I organize them actually by ability but in generally they are at the same level of ability. So I give them freedom to organize their own groups. However I

> consider social concerns and so I also suggest to them that they should have both male and female students in the same group. (1st Interview: Benja, Jul 30th, 2008)

She described her reason for allowing students to work together as the way to develop thinking skills and eventually to achieve understanding:

> When I have them work together I think it is good because they can help each other, think together, and fulfill each other. In addition when their pair work is done they can go and share it with others, to compare and contrast. In this way they can get diverse answers. This make them think about the difference. This way, I think, is better than just listening to the teacher." (1st Interview: Benja, Jul 30th, 2008)

Even though Benja promoted cooperative learning in her classroom she did not devote much of her time to preparing the lesson for cooperative learning. She just solved her problem at hand by assigning students to work in groups when she saw that students could not answer her question on their own. In the groups, students answered each other's questions and worked together to reach a common goal.

To organize students into groups, she did not take into much consideration the different learning skills, personalities and gender types. The groups were arranged freely by students, in line with her belief that they were not of significantly different learning capabilities. As regards the effectiveness of group learning, she had no chance to discuss special needs or problems with students about group learning. In addition, students had no chance to express their feelings about beneficial and unhelpful aspects of the group learning activities in order to correct unwanted behavior and celebrate successful outcomes in the group work.

Learning Assessment

In Benja's classroom there were three learning assessment methods, consisting of students' answering questions, being observed and submitting reports. The functions of the assessment were to diagnose learning problems, to encourage better learning, and to evaluate learning achievement.

The Use of Observation

One of the obvious ways to assess learning was through observation of student behavior, as when Benja walked around the class. Benja used observation to see how students dealt with problem solving and their learning difficulties, how they interacted with other students, and what their study habits were. The student's performance was marked down in terms of both positive and negative aspects. She explained that she used observation as one assessment method by talking to the students, walking around and observing what students were doing and achieving:

> I measured in overview such factors as attitude or cooperation. I practically had no assessment tool in checking students' behavior, but I simply observed how they worked in their group, whether they worked cooperatively and shared together. When conducting the experiment, I observed whether they did it according to the right procedure. I would give them a score for doing the experiment and writing up the experimental report. Group work was considered as an affective domain which I checked every time I taught. However both observation and students' reports did not provide me with adequate information about student learning outcomes because it was only a part of the assessment." (4th Interview, Benja, Aug 28th, 2008)

Observation was used as a part of Benja's assessment, and was intertwined with the learning process so that it provided information as to the success of the students' learning.

The Use of Questioning

Benja probed student's understanding and reasoning through questioning. Throughout a lecture and the teacher's explanation of a topic, she posed questions, and students were asked to pair off and work in groups and to respond to a question. The students were asked to show either their solutions or conceptual understanding, and to submit it to class discussion. She used this method to encourage students to share their comprehension of and viewpoints on course material. As well, she used this method to encourage students to problem solve in order to answer a question or address an issue. She also emphasized the greater importance of creating better questions, rather than just getting the right answers, to prompt student thinking. The assessment tools were varied and embraced the multiple facets of learning based on each student's pace. Similar to observation, this method of assessment was intertwined with classroom teaching and learning activities.

The Use of Student Reports

Aiming at assessing students scientific skills, Benja asked students to write up the lab report of every experiment. She emphasized student work that needed to be systematically reviewed for evidence of successful learning. Therefore she asked students to write lab reports which contained the following aspects: title; aim of experiments; hypothesis; chemicals and materials; methods which provided a full account of the experimental procedures; results which included all the experimental results, with appropriate graphs or tables; and discussion which contained the interpretation of the results in the light of current knowledge of the subject and drew appropriate conclusions.

The assessment of the lab report was based on the teacher's judgment, with no criteria or directions given. As the teacher was the only person to assess these reports, she always discussed with students so as to reach agreement with them as to the composition of the lab report, and students took note of what the teacher had said before writing their own report. Therefore almost all the reports of every group of

students were quite similar. Benja reasoned that she needed to discuss with students about the detail of the experiment, which would be addressed in the lab report. Thus they were able to write correctly as much as they could. On the other hand, if she did not tell them the details to write up, they would come up with diverse answers or explanations that she could not correct for them. This method and the reason she gave for it revealed that the assessment tool and assessment methods were not consistent and that she could not fully assess whether students really understood.

Teacher Roles

As a classroom teacher, Benja played various roles in the facilitation of student learning.

The Information Provider

Although this study has shown that Benja used various teaching methods, she did present some of her material by explanation. She used explanation for presenting information which was new information, in particular factual information which was not readily available to students from elsewhere, or material that was too complex for students to grasp on their own. In her practice, she acted as an information provider to provide summarizations of conceptions, to draw together diverse elements and to show connections between concepts. However, during her explanation, she used examples and illustrations to assist with explanation, and incorporated brief discussions, and question-and-answer sessions into her explanation to support students' engagement in learning activity and to promote understanding.

The Learning Facilitator

In Benja's classroom, students' understanding was a product of the combined efforts of the teacher and the students. Benja acted primarily as a facilitator. Benja considered various factors as she provided and developed the learning opportunities to facilitate student learning. Benja placed considerable emphasis on

getting to know individual student capabilities through using questioning to establish students' prior knowledge and in order to address their incomplete understanding. During the learning process, her means of facilitating learning were: involving the students in the learning activities, questioning, listening and providing feedback, establishing guidelines for the learning process, and monitoring the learning process. Under the guidance of the teacher, the students synthesized the gathered information using problem solving, critical thinking, and inquiry skills.

To involve the students in the learning activities, Benja ensured that they were active in their own learning, whether that activity was physically doing something such as an experiment, or intellectually doing something such as analyzing and concluding the experiment. The students were able to collaborate with others in the learning process; the students were able to shape the learning process so as to have some control over what was learned and the direction of the learning. Benja described how she facilitated learning by asking students questions and dealing with their responses:

> When I use questioning or whatever, naturally students can explain either rightly or wrongly. Whichever way they answer, I should inform them whether their answer is right or wrong, and explain the weak points which indicate that they do not fully understand the material. (2nd Interview: Benja, Aug 1st, 2008)

She gave an example of one lesson in which she was teaching about chemical equations, and during which she used a lot of questions to help students reach a conclusion and prompt them to think:

> It was so slow today because the experimental result was in error, which made it difficult to arrive at a conclusion. I asked them a lot of questions in order to help them reach a conclusion. I used questioning to help them see what the result really should be, and as a result they eventually could explain and give reasons for the conclusion. Teaching was not only telling them the facts. On the other hand I told them they should not keep quiet when I was teaching. They

should both ask questions of the teacher and answer the questions posed. (2nd Interview: Benja, Aug 1st, 2008)

In brief, to the end of facilitating student learning, Benja accepted her responsibility to know the capabilities of her students and to improve any incomplete understanding they might have of the material prior to their learning a new concept. To this end she involved the students in the learning activities through both physical hands-on and intellectually engaged activities. As well, she provided feedback and established guidelines to help students successfully conclude the learning process.

The Learning Assessor

In order to get to know the student before teaching a new concept, the student's level of understanding was assessed as a means of developing learning opportunities. Benja took her role as learning assessor seriously, designing simple assessments of what students already knew, and using oral questioning as a bridge to what she wanted students to learn. The students were selected randomly and asked about what they knew on the current concept:

To assess students' learning during the learning process, Benja designed the assessment tools to test students' learning, including questions to assess student understanding of the concepts. In addition, she used observation to assess student skills and attitudes. Benja described her practice about how she assessed student's learning through her observations:

> I emphasized content and activity when I chose learning assessment methods. I myself created the criteria for learning assessment. It was based on what I was measuring: conceptual understanding; skill; or attitude. I measured in overview such factors as attitude or cooperation. I had no fixed plan but I observed how they worked together in their group, whether they worked cooperatively or shared together. When conducting the experiment, I observed whether they did it with the right procedure. I would give them a score for conducting the

experiment and writing up the experimental report. Behavior in group work was considered as an attitude domain, which I checked every time I taught. (4th Interview: Benja, Aug 28th, 2008)

The results of assessment were rarely revealed to students because of time constraints. However, the key concepts, which were assessed by means of a written exercise, were clarified through class discussion and by giving the key answer to the students. In this way students could know about the result of their assessment at once. In brief, as regards learning assessment, Benja took two main responsibilities: designing the assessment tools, and assessing student learning including conceptual understanding, skills, and attitudes.

Summary

In summary, in Benja's classroom, understanding came both from the teacher and from students' participation in questioning and hands- on activity. Benja acted primarily as a facilitator. Benja considered various factors as she provided and developed the opportunities to facilitate student learning. Benja placed considerable emphasis on getting to know student capabilities through using questioning to establish students' prior knowledge, before linking it to the new concept. However, in her use of questions for assessment, the prior knowledge of only some students was uncovered. Under the guidance of the teacher acted as facilitator, students had an opportunity to talk and do simply group work together, without constant teacher monitoring. Benja also facilitated learning activities by providing feedback or correction when questions from student arose. As regards learning assessment, Benja fulfilled her role as an assessor who evaluated student learning in all domains, and who aimed to diagnose learning problems, encourage better learning, and evaluate learning achievement. However some assessment tools and assessment methods were not consistent, which meant that she could not fully assess whether students really understood.

Common Findings among the Three Cases

Common findings were derived from a cross-case analysis of the three in-service chemistry teachers' teaching practices. The common themes that emerged in the findings are presented below.

The Teachers Were Not Much Aware of Students' Prior Knowledge as a Part of Learning Process.

Asking for prior knowledge was used to encourage students to think about their understanding of the current concept, and in turn could help the teachers to shape the knowledge and learning activities in the learning process. In teaching new concepts the approaches used by these three teachers to introduce the concepts were different, often consisting of some combination of two paradigms of teaching: the constructivist teaching approach and the traditional teaching approach.

All three chemistry teachers carried out aspects of their teaching practices in accordance with the constructivist approach, in which they placed considerable importance on their students' previous experience, and so asked about and reviewed their students' previously acquired knowledge so as to help them re-shape their understanding of previous concepts, clarifying incomplete pre-existing understanding of previous knowledge, or relating it to the new concept (Yager, 1991; Brooks and Brooks, 1993; Windschitl, 2002; Baviskar, *et al.*, 2009). Regarding eliciting students' prior knowledge, they still did not become very aware of students' prior knowledge which was largely ignored before teaching the new concept. The teachers were more concerned on giving and covering the content knowledge, which made their approach similar to traditional teaching (Ruddell, 1992). However the teachers performed their teaching practices differently, based on their differing backgrounds in constructivist teaching, understanding, and experience. Benja who has the most experienced in teaching based on the constructivist approach, demonstrated her familiarity with that approach by often asking about the relevance of students' prior knowledge to the new concepts before introducing the new concept. However the technique she used in

eliciting student's prior knowledge was based only on questioning, and it did not cover all students. Aree, who has some experience in teaching based on the constructivist approach, demonstrated in her practice that she had some understanding of how to elicit students' prior knowledge. She did ask for students' prior knowledge in the case of one topic out of all the topics covered, as was observed from her teaching. Even though she asked students for prior knowledge in this case, she did not link students' prior knowledge to the new concept. In addition some questions she asked were of minor relevance to the new concept. Dara who has less experience in teaching based on the constructivist approach, demonstrated in her practice an extreme adherence to traditional teaching, wherein she seldom used questioning and other class activities to activate student's prior knowledge. She placed most emphasis on transmitting content rather than asking for student's prior knowledge to help shape their understanding or facilitates the learning activities. Before teaching every topic she stated and wrote out the topic titles, and followed this with giving students content knowledge.

The Teachers Were Overly Concerned With The Students' Understandings Of Content Knowledge Rather Than Students' Processing Of That Knowledge.

All three chemistry teachers carried out the fundamental purposes of organized learning activities, and similarly sought to convey information to students and to help them achieve conceptual understanding. However, the approaches to teaching were different, often consisting of some combination of two paradigms of teaching: the constructivist teaching approach and the traditional teaching approach.

Based on the constructivist teaching approach, Aree and Benja had similar teaching practices in which they used questioning (Tytler, 2002; Windschitl, 2002). However, all three teachers demonstrated that aspects of their practice still adhered to the traditional teaching approach in which teachers had absolute authority over students' s learning and which emphasized teaching based on the textbook (Huck and Kuhn,1968; Miller and Seller, 1985). Dara who had less experience of teaching based on the constructivist approach, always relied on a traditional approach to teaching through lectures and demonstrations to transmit content at a faster pace, rather than on

having the students actively participate in the learning process (Huck and Kuhn,1968; Miller and Seller, 1985). In her teaching, the process tended to be passive, with the students receiving knowledge passively and having less autonomy in their learning process (Huck and Kuhn, 1968; Miller and Seller, 1985). In addition, rote memorization often was mentioned by Dara as one main method meant to help student learning.

Aree used teacher's explanations and experiment to facilitate teaching and learning in her classroom. The information was not directly transmitted from teacher to students but rather disseminated under the guidance of the teacher though asking questions and providing explanation. However, in her class, teaching and learning still adhered to the textbook-centered traditional teaching approach (Huck and Kuhn, 1968; Miller and Seller, 1985). Even though laboratory experiments were included, students were rarely encouraged to use scientific methods to solve problems relevant to their perception of the world. She posed the problem of the experiment as well as taught the experimental procedure, all based on the textbook, so that students were only being asked to do the experiment in conformity with the textbook. After the lesson, the knowledge was further transferred to the students through their doing the assignment, a task which was emphasized in Aree's practice.

Benja incorporated class discussion into her explanations and into the experiments as well, in order to facilitate teaching and learning in her classroom. The bulk of information was transmitted under the guidance of the teacher to help students construct understandings through asking questions. As regards the experiments, even though Benja allowed her students themselves to conduct them, yet typically students arrived at the laboratory to do an experiment without a clear idea of the main concept of what they were studying. She exercised control over students in conducting the experiment so that they conducted it based on the procedure mentioned in the textbook (Huck and Kuhn, 1968; Miller and Seller, 1985).

The Teachers Encouraged Students to Learn And Work as a Group, Which However Did Not Support All Aspects of Cooperative Learning.

In organizing students to learn and work in groups, the three chemistry teachers had a similar purpose, which was to encourage the students to learn together. All three chemistry teachers practiced their teaching based on a constructivist approach in which they tried to incorporate group learning into their classroom activities (Yager, 1991; Tytler, 2002). Benja used face-to-face interaction to help students to learn. Aree supported cooperative learning in the form of positive independence in which each member helped the others to complete their own work. Dara planned to use the technique of Numbered Heads Together in her class (Kagan, 1991).

However, the approaches in using group work did not encompass all aspects of cooperative learning in their classrooms; teachers allowed students to work in groups to reinforce concepts taught by teachers, but it was simply students teaching students and simply group learning activities that it was not cooperative learning (Johnson, Johnson, and Smith, 1991; Johnson and Johnson, 1987).

Dara primarily planned to group students in groups of four to five students based on a cooperative learning strategy, Numbered Heads Together (Kagan, 1992). In her practice, students were put into groups but students learn by themselves from the instructional material provided to the group. Students were assigned to work alone. She did not emphasize on group processing that students had interaction to finally reach the common goal together.

Aree primarily planned to group students in groups of four to five students, but in her practice the students were not organized as expected because the physical environment was not sufficient for smaller groups. In her classroom, she tried to promote cooperative learning by encouraging positive independence for each group member, with each being held responsible for his or her own work. However the group working by this interaction was not very effective since some individual students did not do much to help other members to accomplish their task and still worked alone. The

group did not explicitly set the stage for students to learn social skills. Students were not informed about group roles such as: leadership, decision making, and trust-building. Only the communication skills were developed in actual cooperative learning, when students did the experiment. How groups were functioning to achieve their tasks was reviewed only by the teacher. In brief, there was no real cooperative learning in her classroom because there was no real interdependence, no individual accountability, responsibility only for self (Johnson, *et al*., 1991). In addition, the students and Aree had no chance to discuss special needs or problems within the group learning, in order to correct unwanted behavior and celebrate successful outcomes in the group.

Benja believed that cooperative learning works best when group size was smaller. In her classroom, students were organized into groups of five students. Benja promoted face-to-face interaction to ensure students' understandings by asking students worked in pairs or in groups depending on the purpose of the activity such as two-minute discussion. Students answered each other's questions and worked together to reach a common goal. However she did not devote much consideration to students' background, for example, such issues as capability and gender, when arranging groups. The groups were arranged freely by students, in accordance with her belief that student learning skills did not differ all that much. In addition, she only had students to work in group by simply discussing with somebody who sat nearby when she saw that students themselves could not answer her questions. The aim or of incorporating group work into the lesson was not clearly conveyed to students. Benja was only one who assessed group processing how well it benefited student learning in her class. However, the students and Benja had no chance to discuss special needs and problems of the group work in order to correct unwanted behavior and celebrate successful outcomes in the group's work.

The Teachers Used Various Assessment Methods Which Emphasized Only on Cognitive Dimension of Student Learning.

The fundamental purpose of conducting assessment among the three chemistry teachers was similar in evaluating student learning in all domains: conceptual

understanding, skills, and attitudes. However, the approaches to conducting assessments were different, consisting of two paradigms of teaching: the constructivist and traditional teaching approaches.

All three used some aspects of assessment approaches compatible with a constructivist view of learning. They used several learning assessment methods to assess students' learning (Brooks and Brooks, 1993; Windschitl, 2002). Benja placed more importance on creating better questions to prompt student thinking, rather than on the importance of right answers. The assessment tools were varied to embrace the multiple facets of learning based on a student's pace. Furthermore, assessment was intertwined with classroom activities, including questioning and observation. The results of assessment were used to discover any learning difficulties. The functions of the assessment were to diagnose learning problems and to encourage better learning. Aree used various learning assessment methods and tools which included asking questions, assigning exercises, observation, and multiple choice paper tests as the main assessment methods. She used questioning, exercises and observation while teaching to monitor and to diagnose learning problems which she could then address in her teaching to encourage better learning. Dara also sometimes used observation to assess student behavior in her class.

On the other hand, all three teachers still largely conducted themselves in accordance with traditional teaching methods which they taught to cover all to information prescribed in textbook. They asked or tested students aiming at getting only right answer. They assessed student learning and understanding, which emphasized on test which separated from teaching activities, and emphasized only the cognitive dimension of students' learning outcomes (Miller and Seller, 1985). In addition, these three chemistry teachers were alike in terms of their roles, in that the individual teacher decided what to assess, how to assess it, and how to respond to the information gained through the assessment (Ruddell, 1992).

Dara used a work sheet that clearly delineated the right answer from the other answers as the main method of various learning assessment methods (Miller and Seller,

1985). In addition, questions were often asked when she interacted with the students. Dara was not very concerned as to how or why either knowledge or the student's answer was obtained, but she was rather concerned to get the right answers from the students. The results of assessments in the classroom, such as asking questions and answering the worksheet, were not obviously used to monitor the students' understandings or to encourage better learning. Rather, she emphasized tests, which were separated from teaching and learning. The other dimensions of leaning, such as skill or attitude, were ignored in her classroom. Aree still adhered to tests and used them after finishing teaching (Miller and Seller, 1985). The results of the tests were recorded and used as a commutative score for students' achievement. The other dimensions of successful learning, such as skill or attitude, were ignored in her classroom. Benja still adhered to the right answer or right report paradigm when asking students to write up their laboratory reports (Miller and Seller, 1985). She had already told students how and in what manner to address the material in their reports. Therefore students used their notes to re-write their reports, which for that reason were similar to those of others in their group. By this method she could not really evaluate student's understanding and experimental skills.

The Teachers Played Various Teaching Roles to Support Student Learning While Retaining Considerable Authority Over Student Learning.

The teachers played their various teaching roles with much the same fundamental purpose: to improve student achievement. They played their roles by drawing upon constructivist principles in order to facilitate student learning (Brooks and Brooks, 1993). However the difference in their teaching with regard to the constructivist approach made them act out some of their roles differently. Benja played a role mainly as facilitator as well as information provider. She used questioning and hands-on activities to encourage student learning. In addition, she used questioning to establish students' prior knowledge and correct any incomplete understandings. Aree acted as facilitator to provide feedback or correction when questions from students had arisen. In addition she also facilitated student learning by creating and adopting some

instructional materials to enable students to learn more easily. Dara acted as resource developer and used those materials to help students learn.

On the other hand these teachers continued using traditional methods which envisaged teachers as being the main information provider, individual planner and assessor (Huck and Kuhn, 1968; Miller and Seller, 1985; Ruddell, 1992). Dara in particular adopted a traditional teaching role in which the teacher assuming a lot of responsibility in the learning process. She fulfilled the roles of information provider, planer and decision maker, and assessor. In her practice, information primarily came from the teacher. She used her expertise in content knowledge to help students make connections, usually with the teacher talking and the students listening. When planning the lesson, Dara acted as planner as well as decision maker for the what-and-how of the learning process, for which she relied on the textbook. The effort to get to know the students and to understand how they processed information was secondary. As regards learning assessments, Dara usually monitored and corrected students' answers and their work. However some students' answers and work were not corrected and this left them confused. In her classroom, only the teacher acted as assessor to evaluate student learning (Ruddell, 1992). Aree played her roles as information provider along with being a facilitator to encourage student learning. As regards learning assessment, Aree acted out her role as an assessor who evaluated student learning (Ruddell, 1992). In the case of Benja, even though she played her role as facilitator, she mainly still focused on the matter in the textbook (Miller and Seller, 1985). Her teaching remained strictly based on the textbook and more concerned to adhere to the school curriculum, which affected what and how she planned teaching and learning activity in her classroom. As regards learning assessment, Benja, like the other two chemistry teachers, acted as an individual assessor to evaluate student learning, without asking students to participate in their learning assessment (Ruddell, 1992).

Summary

The teaching practices of these chemistry teachers revealed that to a considerable degree they remained tied to traditional teaching methods. These practices

included such aspects as: (a) a lack of awareness on the part of the teachers eliciting of students' prior knowledge, which was a part of learning process; (b) a primary concern by the teachers with the students' understandings of content knowledge, rather than focusing on students' processing; (c) their encouragement of the students to learn and work as a group, which did not support all aspects of cooperative learning; (d) their use of various assessment methods which emphasized only the cognitive dimension of students' learning outcomes; and (e) their assumption of various teaching roles while retaining considerable authority over student learning. In Chapter 5, an interesting issue of how in-service chemistry teachers can develop and transfer their constructivist approach from a collaborative action research group into classroom practice is presented.

CHAPTER V

RESULTS OF PHASE II OF THE STUDY

Overview of the Chapter

This chapter provides the results of the analysis of the multiple data sources used to answer the second research question, namely: "What is the influence of a Collaborative Action Research project on the chemistry teachers' teaching practices based on a constructivist approach?" The changes of the teachers' teaching practices based on the constructivist approach, the focus of the action research group, was considered in terms of what the teachers understood and what they practiced. Within each case of the study, personal teaching practice changes based on the constructivist approach and its components in the collaborative action research approach are presented.

Throughout the second semester of 2008 academic year, the teachers were observed in their teaching practices two times monthly during November, 2008 to February, 2009. The teachers were interviewed before and after teaching each lesson. In addition, they were asked for the lesson plans based on topics they were teaching. The data were collected and teaching practices were observed in the classrooms of students who were studying in the science program, which were the same groups as the previous semester.

However, because of school activity, political issues, and the difference of length of lesson, I was not able to collect the data and observe teaching practice as expected. For this reason, Dara was observed in her teaching practice for five lessons. Each lesson was allocated for 2 hours. The topics observed were molecular shape, molecular polarity, properties of chloride and oxide compounds, chemicals reactions of elements group IA, IIA and VIIA, and law of conservation of mass and law of definite composition. Aree was observed in her teaching practice for four lessons. Each lesson was allocated for 3 hours. The topics observed were: units of solution concentration,

preparation of solution, properties of solution, and chemical equations. Benja was observed in her teaching practice for four lessons. Each lesson was allocated for 4-6 hours. The topics observed were dynamic equilibrium, the relationship between concentrations of the reactants and products at the equilibrium state, the electrolysis of acid-base solutions, and the electrolysis of water.

There were three cycles of the collaborative action research. The activities in each cycle consisted of one group meeting held at Kasetsart University, which occupied approximately 3 hours. After the group meeting I was considering how each teacher performed and changed their practice by observation, interview, and analysis of teacher's lesson plan, 1-2 lesson a cycle based on what they were teaching as mentioned earlier. The first cycle took place during November 8th to December 5th, 2008. The second cycle, December 6th, 2008 to January 9th, 2009 and the third cycle, January 10th to March 13th, 2009). The activities in each single cycle are already described in detail in Chapter III. The following section of this chapter presents how, in each case, the teacher's personal teaching practices changed, based on the constructivist approach.

The Case of Dara

Lesson Introduction

Way of Changing Practice in Eliciting Students' Prior Knowledge

Regarding her understanding of prior knowledge, Dara stated in the first meeting that she felt that students' prior knowledge was the understanding of previous concepts:

> Prior knowledge is what students have learned in the former grade level. For example, as I watched the video of Benja's practice, the questions she asked for prior knowledge of this 11th grade concerned the previous concepts students had learned in 10th grade. (1st Group meeting: Dara, Nov 8th, 2008)

As Dara and the other two teachers had a limited understanding of student prior knowledge, facilitator 2 and I therefore explained to teachers that asking about prior knowledge was eliciting how students understood the concept we were teaching, in order to provide teaching and learning activities suitable for students. After discussion about the importance of prior knowledge and how to elicit student's prior knowledge, Dara adopted what she understood from the first group meeting to develop her lesson plan. However, she still had a limited understanding of prior knowledge, as she explained below:

> I will ask students about molecular structure, aiming to elicit their prior knowledge which they have learned prior to learning the new concept about molecular shape. In this step I will not ask about molecular shape yet because students have not learned and conducted the experiment on this topic. (Interview before teaching: Dara, Nov 24th, 2008)

From Dara's explanation about her lesson plan, there was not any question to elicit prior knowledge. I suggested her that: "We should ask one more question, such as: from those molecular structures, how it takes molecular shape?" (Interview before teaching: Dara, Nov 24th, 2008). However in her practice, prior to teaching about molecular shape, she asked students to write out the Lewis structure of oxygen gas (O_2) and chlorine gas (Cl_2), and then asked them to indicate a pair of electrons being bonded in that molecular structure. Next, Dara told students what they were going to study in this class, so that students could explore the shapes of molecules by arranging the round balloons. No question was asked about how students understood molecular shape before teaching this concept.

In this first lesson, Dara still struggled with eliciting students' prior knowledge and her practice demonstrated that she did not really ask about her students' prior knowledge before teaching new concept. Most questions were asked in order to review the previous concept that students had learned in previous classes.

In the second cycle, in teaching about molecular polarity, Dara still thought that asking about a previous concept such as molecular shape, was a question to elicit students' prior knowledge of the molecular polarity concept. One excerpt of class observation illustrates her limited understanding:

> First I would ask you which element group (in the periodic table) has the greatest electronegativity values. Electronegativity is the attraction that an atom has for shared electrons in a covalent bond . . . We have learned (the concept of electronegativity). This is to review your prior knowledge. (Classroom observation: Dara, Dec 9th, 2008)

However, in the second topic of the second cycle, teaching about the properties of chloride and oxide compounds, after talking with me about how to elicit prior knowledge, she finally could develop her lesson plan that incorporated some questions used for eliciting students' prior knowledge: How do you think when chloride compounds are dissolved? Should they be acid, base, or neutral? In her practice, she asked these questions and in the meantime she used such questions as a way to link to new information.

Even though, in the last topic of second cycle, Dara was able to develop some questions to elicit students' prior knowledge, she still did not understand clearly how to elicit prior knowledge when she had to teach other concepts. In the third group meeting, Dara presented her lesson plan and then raised one question to ask about how to elicit prior knowledge. One excerpt of group discussion in assisting Dara to understand clearly how to ask for prior knowledge, it is illustrated here. The dialogue below reveals how all teachers learned together in the third group meeting:

Dara: In this topic I talked to students about chloride compounds. If we had chloride compounds, how could you explain about their melting points or boiling points and how about their solubility? For example, asking for prior knowledge, how does sodium chloride dissolve in water?

Benja: If I were you, to elicit prior knowledge about some chloride compounds, I would ask questions like these: Are these compounds dissolved in water? How about their acidity or alkalinity if they are dissolved in water? Are they similar or different?

Dara: Can I ask about melting point or boiling point?

Benja: Not yet. You have to conduct the experiment about their solubility first, and then move on to the new concept (about melting point or boiling point).

Aree: Yes, I do agree with Benja.

(3rd Group meeting: Jan 10th, 2009)

As a result of the third meeting, Dara was eventually able to develop questions, and she used these questions in eliciting students' prior knowledge of the last two lessons. In teaching reactions of the elements of group I, II and VII, the questions for eliciting students' prior knowledge were: 1) Regarding other compounds of group I and II, such as the sulphate compound and the carbonate compound, what happens when they are dissolved in water? 2) Are these compounds dissolved? In teaching the law of conservation of mass and the law of definite composition, the questions for eliciting students' prior knowledge were: If there was only a solid precipitated without any gas compound produced, was the mass of the reactants before the reaction had taken place equivalent to the mass of the products after the reaction had taken place?

In summary, Dara gradually changed her practice in eliciting students' prior knowledge before introducing new information. In the first semester she always launched the class by introducing the title of the lesson, and she then conveyed the information to students by mostly using lecture method. In the second semester, in the first meeting, she began to learn about how to introduce the lesson by activating students' understandings of what was being taught prior to teaching the new concept. However, when she adopted the principle of eliciting students' prior knowledge into her practice, it was clear that she still did not understand and that lead to her not providing any question or activity to elicit students' prior knowledge. Dara raised her

difficulty in eliciting prior knowledge in the group meeting, listened to the group discussion, and learned from Aree's lesson plan possible ways of eliciting prior knowledge. Dara later applied what she understood to plan her lesson with assistance from myself during one-on-one discussions at her school. Dara changed her practice a bit to elicit students' prior knowledge in that in one of two lessons a question was raised to elicit students' prior knowledge. However, Dara still did not clearly understand how to ask for prior knowledge, in cases where there were several concepts in one topic. She then raised this concern in the third meeting and she encouraged other teachers to share their understanding. After the group discussion and one-on-one discussion with me, Dara finally created appropriate questions to elicit students' prior knowledge and applied these questions in her class.

Learning Activity

Ways of Encouraging Students' Participation in Their Learning Process

Dara described her teaching method that: "I taught by using learning centers . . . before I asked students to study in these centers I had already lectured them in order to convey all information. The learning centers were used for reviewing what they had learned." (1st Group meeting: Dara, Nov 8th, 2008) Dara did not know about constructivist approach or even the teacher role based on this approach. As she said, "I myself actually still was not clear about the constructivist approach. In my opinion, the constructivist approach is students being able to summarize all concepts by themselves." (1st Group meeting: Dara, Nov8th, 2008)

After Dara first learned about the constructivist approach in the first group meeting, she then developed her lesson plan as a guide to teach based on this approach. Even though we discussed how to encourage students in the construction of their understanding before Dara taught the first lesson, she still believed that conveying the information was the most important thing: "I will use a demonstration showing how molecules are shaped, instead of allowing students to do hands-on activity, in order to finish the activity faster." (Interview before teaching: Dara, Nov 24th, 2008) In her teaching about molecular shape, the three main opportunities provided for students to

get involved in the learning process were: through responding to the teacher's questioning, seeing the teacher's demonstration, and doing the exercise.

She told students what activity they were going to do and asked one student to read the experimental procedure from the textbook. She asked students to set out a hypothesis: "Tying together different numbers of round balloons will give us a different shape?" Then she wrote the hypothesis on the blackboard and drew a data table to identify key information to be recorded. Dara began demonstrating how to tie the balloons for the students, and then asked students the following questions regarding the shape of the balloon tied and its angle: "If I tie two balloons together what is its geometrical shape?" (Linear) "Is the bond angle of linear shape?" (180^{o} bond angle) Throughout Dara's demonstration the students just observed and related to her the balloon shapes. After the experiment she continually explained how to predict molecular shape by using the Valence Shell Electron Pair Repulsion Model [VSEPR]. She used questioning to prompt students to think about chemical formulas of various elements, their structures, and their molecular shape that matched to VSPER. To conclude the lesson, Dara asked questions so as to have students indicate what the molecular shapes of each element group in the periodic table were.

Dara still controlled learning activity and was overly concerned to provide information. What was a bit of a change from the previous semester was the fact that Dara asked more questions to encourage students to get involved in activity. However because Dara still told students the experimental procedure without any discussion, after teaching I therefore met Dara and then we talked about how to discuss before conducting the experiment so as to have students understand clearly why they had to conduct the experiment and follow the given procedure.

In second cycle, even though Dara did not share her experience of teaching, she was good listener and learned from other teachers' practices how to formulate some questions aiming to engage students in learning activities and to assist students to construct their understanding. After the second group meeting Dara demonstrated a bit of change by putting less emphasis on conveying the information encouraging students to think about what they were studying. During classroom observation, after Dara and

the students finished with the main concept of molecular polarity, she then encouraged the students to participate in learning activities by asking several questions. For example, some questions were posed when explaining the molecular polarity of the ammonia molecule (NH_3), and included: 1) Who would like to draw the NH_3 molecular diagram? 2) Which group of elements does nitrogen belongs to? 3) How many of the fifth group of elements can be bonded? 4) How does NH_3 take shape? 5) How can we draw pyramid shape? 6) Which atom does the arrow point to (between N and H)? 7) Is the NH_3 molecule a polar molecule? With each question, the students were engaged in a dialogue and expressed their opinions, and this eventually led them to solve the problems presented together.

Another lesson taught in the second cycle dealt with the properties of chloride and oxide compounds. She used an experimental demonstration as her approach to teaching these concepts by asking four representative students to do a demonstration, justifying this with the excuse that the classroom was not appropriate for all students to conduct the experiment. To involve students in the learning activity, she used questioning to challenge students to set out a hypothesis about acidic and alkaline properties, to discuss what they should observe, and to ask them to formulate a conclusion to the experiment. The dialogue below is an example of how Dara discussed the experimental procedure with students:

Dara:	What indicator can you use for testing acidity or alkalinity?
Students:	Litmus paper.
Dara:	How can you design a data table and what terms should be recorded?
Students:	The type of chemical and its solubility.

(Classroom observation: Dara, Dec, 23rd 2008)

To conclude what had been learned, Dara asked what students had observed and discussed the results to conclude the experiment. The questions were used at the post experimental discussion, such as: 1) From your observation, in how many groups can

you group the chloride compounds? 2) Which group of chloride compounds produced acidic solutions? 3) Which group of chloride compounds produced neutral solutions?

In these lessons, what obviously changed from the previous semester and the first lesson was that Dara asked more questions during learning activity. Regarding conducting experiment, Dara gave more opportunity for some students to do the class demonstration rather than doing it alone. In addition, she asked more questions during pre-experimental discussion and during the experimental conclusion, which contrasted with the previous semester when she only told students what they were going to do and seldom held a class discussion.

In the third cycle, Dara was primarily concerned about giving an opportunity for students to become involved in the learning activity as much as possible. As she said, “Even though I could not allow all students to conduct the experiment, I would ask for sixteen students to take turns in the demonstration.” (Interview before teaching: Dara, Jan 12th, 2009)

During classroom observation, Dara stated the central idea of the activity: solubility of the IA group element compounds and the solubility of IIA group element compounds. She then asked for the hypothesis through the following question: “If we mix the following solution, which is made up of IA group elements compounds and IIA group element compounds, are these solutions dissolved similarly or differently?” (Classroom observation: Dara, Jan 20th, 2009) Next, she explained how to conduct the experiment as follows: “I need sixteen students to conduct this experiment.” Dara then explained the experimental procedure and what students should observe. She encouraged students to discuss how to design the data table. At the end of the activity she discussed what students had observed and asked the representative students to fill in the data table with what they had observed. To conclude the experiment, she asked students some questions concerning how to group compounds of groups IA and IIA by their solubility. After the experiment the students were asked to do the exercises which would help them to understand the concept more clearly.

In summary, regarding the need to encourage student participation in learning activity and assume some responsibility in their learning, Dara used three main approaches consisting of: questioning, having students conduct an experiment, and doing the exercise. Dara realized that there were several weaknesses in her teaching, and she felt that she would like to improve her teaching next time. Dara increasingly used questioning which she had emphasized less in the previous semester or even in the first cycle, but gave it much more emphasis in the later cycles. In the second and third cycle the questioning was more emphasized before, during, and after teaching. Regarding conducting the experiment, she increasingly encouraged students to discuss about what they were going to study, including such topics as formulating the hypothesis, discussing the experimental procedure, and/or designing the data table, as well as making an experimental conclusion, in contrast to the previous semester when she always did those aspects by herself. Even though throughout the learning activity Dara was the one main person who controlled the learning process, a gradual change was taking place in each cycle. In the first cycle nobody was asked to get actively involved in conducting hands-on activity. In the second cycle a few students were asked to assist the teacher demonstrating the experiment. In the last cycle, more students were asked to participate in conducting the experiment. As to the exercise, Dara had developed the exercise so as to fit class activity from the first cycle to the third cycle, so that students could practice what they had learned.

Social Interaction in Classroom

Journeys to Incorporate Cooperative Group Learning into the Classroom

Regarding her understanding of cooperative learning, Dara stated in the first meeting that: “As I watch Benja teaching, I think there is cooperative learning in her class. Students always exchange their thoughts with their peers. I mean they keep talking.” (1st Group meeting: Dara, Nov 8th, 2008)

At the beginning, Dara had a limited understanding about cooperative learning or even group work. During the group meeting, facilitator 2 and I introduced all

teachers to features of cooperative learning activity and we then gave the teachers some examples of cooperative learning activity. After the group meeting, Dara adopted what she understood to design her lesson plan. However, she was seriously concerned to design group activity: how she could do this, how many students to fit into each group, and how much activity was appropriate for each group. After she had discussed with me, she eventually decided to have five to seven students per group to work on the given questions. She thought students could use this opportunity to discuss and to work together.

During the learning activity, Dara announced to students that they had to work as a group in doing the exercise: "Work cooperatively and share with each other, let you and your members compete with other groups; I will observe whether you work cooperatively. Discuss with your group members what the shape (of the molecular) is?" (Classroom observation: Dara, Dec 2nd, 2008) After teaching, Dara shared her view on the students' group learning:

> That was the first time I used group work in my class, and it was not effective since some students still worked individually. For example, a group of three students, the one who had received the question work sheets from me, had had to work alone, and the remainder had not taken any responsibility. (Interview after teaching: Dara, 4th, Dec, 2008)

In the beginning Dara tried to incorporate cooperative learning activity into her classroom. But some students remained working individually. She still had difficulty in organizing cooperative learning activity in her classroom. The assignment as well as worksheets and handouts were not appropriate for the number of students, with the result that some of the group members could not access those instructional materials. In addition, she did not clearly inform students of the aims or procedure when using cooperative learning activity.

As regards the problem about cooperative learning, in the second meeting, Dara also shared her problem about group work to our group: "I also had the same problem

that students did not share with each other. Some still kept talking while others were thinking and working. I mean there were two or three students a group and only one student took responsibility." (2nd Group meeting: Dara, Dec 6th, 2008)

In the group meeting, we discussed about the respective duty of each group member before asking students to do group work. We also discussed how and when we could allow students to do group work. After the second group meeting, Dara changed the number of students from the previous class to allow for only five students per group. They were assigned to answer three questions. She still acted as as assessor to correct their work. The score gained would be equal for everyone in each group.

During one observation, Dara announced the purpose of group work: "We do this activity aiming to promote cooperative group work in which each member has to help each other to work and at the same time each group has to compete with the other groups. Each member in your group would get equal marks on your work." (Classroom observation: Dara, Dec 9th, 2008)

After teaching, Dara shared her view that even though in a real learning context the groups of seven or eight were formed willingly, this was not what she expected. She sensed the improvement of cooperative learning in her class, saying, "Those students now shared and worked together in their group more than was the case in the previous class." (Interview after teaching: Dara, Dec 9th, 2008) Dara further remarked that students paid more attention than when teaching by using lecture, as she had used for teaching the same concept in the previous year.

However she thought her strategy still had problems with organizing group work. The ratio of the students to the number of questions on the assignment was not appropriate. Another topic which was taught in the second cycle was properties of chloride and oxide compounds. Before teaching this concept, during one-on-one discussion, Dara explained that her lesson plan would allot five students a group, like the previous class. Dara and I also discussed about the effectiveness of the group activity in the previous class. What we found was that the ratio of the students to the

number of questions on assignment was not appropriate and only some students in each group took responsibility. Faced with this problem, she decided to change the number of students in group activity by letting students work in pairs.

After her teaching, Dara described an outcome in which she first asked students to work in pairs: “They went to get the piece of paper containing questions from me, talked to their partners to find the answer, and when they were finished they came to me and picked other questions. It seemed they liked this activity.” (Interview after teaching: Dara, Dec 23rd, 2008)

In the second cycle, Dara developed and changed her practice to support cooperative learning activity in her classroom. First she organized a group that fit the requirements of the assignment, and in which each member had responsibility for their work. Second she informed students of the aim and the procedure of group work before allowing students to start their work. Third, she presented the results of learning assessment as a group achievement to students.

In the third group meeting, Dara presented her group activity as one choice that the other two teachers could adopt into their classrooms: “I gave students a piece of paper containing a question. A pair of students went to me and picked one question. After they finished answering the first question they can ask for another question.” (3rd Group meeting: Dara, 10th, Jan, 2009)

In the third cycle, she still used the same approach in encouraging students to do group work. The number of students and assignments were varied for each topic. Even though she still had problems due to organizing group work and encouraging all students to work cooperatively, she mentioned the change about students’ learning together which had taken place in her class: “Students devoted more effort to doing the task. The smart ones could do the task by themselves and the less accomplished ones could study and reach an understanding after studying the work of the smarter ones.” (Interview after teaching: Dara, Feb 3rd, 2009) In addition, Dara described, after participation in the action research group, that she had a better understanding of how to

organize students into small groups so as to help students to take more responsibility for their learning.

In summary, Dara, who was not familiar with cooperative learning, always had students do individual work in the first semester. She gradually learned to incorporate cooperative learning activities into her classroom. She primarily encountered many problems when she designed and implemented her lesson plans. The first concern was about the number of students in a group. The second concern was about the quantity of assignments suitable for a group. Dara had solved these concerns every single cycle, but no specific pattern of group work was used. She developed her practice to introduce cooperative learning activity to students by firstly organizing students into groups and having them work as a group. Secondly, in the second cycle, she developed her practice by announcing the aim of cooperative learning, explaining the procedure of cooperative learning, and the results of students' groups work. Thirdly she still used the same approach used in the second cycle, and she also introduced her approach to the other two teachers as an alternative way of incorporating group work into their classrooms.

Learning Assessment

Students' Learning and a Variety of Learning Assessment Methods

At the beginning, after learning how to assess students in each period of time of the first group meeting, Dara adopted her understanding to design her first lesson plan. There were four main assessment methods consisting of: students' responding to teacher's questions, students' answering in worksheets, hands-on assessment, and observation. She explained each method during our discussion and before teaching the concept of molecular shape: questioning was used to assess students' understandings in each period of time; before, during, and after learning new concepts; worksheets were used to assess students' understandings of the concepts when students worked as a group and individually to indicate the molecular shape of given chemical formulas. The other assessment method was the hands-on assessment in which students were asked to created 3D models of the molecule presented by using the materials provided,

consisting of modeling clay and stalks of matches. Through this assessment method each student was called on respectively, based on their student ID, and they got different chemical formulas assigned to them by the teacher. However, regarding students' behavior during their participation in group activity, Dara told me after her teaching that she did not observe whether or not they worked cooperatively.

In the first cycle Dara developed various assessment tools and used various assessment methods to assess students' learning. The way of using assessment tools and methods was changed form the previous semester that she always mentioned to use midterm test and final test as main method to assess students' understanding. However she still emphasized only conceptual knowledge as her students' learning outcomes, but she put less emphasis on thinking about ways to assess students learning cooperatively. Further Dara still played only a narrow role as assessor, just judging whether students' answers were right or wrong. However, in case students did not work correctly, they were allowed to revise their work.

In the second cycle, the main assessment methods were like the methods used in the previous cycle, consisting of: students' answering questions in worksheets, students' responding to teacher's questions, and observation. In addition, Dara also produced a test as one of the assessment methods. In our discussion before teaching the concept of properties of chloride and oxide compounds she showed me the questions developed for the test. However she still struggled to design the test to assess intended outcomes. Only a part of some main ideas would be assessed and other main ideas ignored. For example, the questions asked only about acidic and alkali properties when the compounds were dissolved in water, but there was no question asking about the melting point and the boiling point, which was one concept she wanted students to understand. Dara and I discussed about what should consider in developing the questions for test. Dara finally modified her test items to be consistent with the main concept and expected learning outcomes. In her practice, she used only student's assignments to assess students' learning. After teaching, Dara told me one problem in respect of assessing students' learning: "Because I was the only one who corrected students' work, a new problem emerged. I had to correct work for every student, which

meant that other dimensions of learning outcomes, such as social or attitudinal dimensions, were not much emphasized." (Interview after teaching: Dara, Dec 23rd, 2008)

However, Dara tried to develop the assessment method aiming at understanding what students thought of her teaching. In the second lesson of the second cycle, she asked students to write about what they learned, what they still struggled with, or even what they would like to recommend about her teaching practice and learning activities in the student's journals, which facilitator 2 and I presented in the first group meeting.

In this second cycle, even though Dara developed her understanding of how to assess students with a variety of assessment methods, she still had difficulty assessing other dimensions of learning such as social and attitudinal dimensions.

In the third group meeting, Dara presented some of her students' journals showing what students thought of her teaching. As a student in Dara's class wrote, "I understand how to prepare oxygen gas and know the application of oxygen gas . . . I still do not understand about chloride compound . . . I like conducting experiments and would like to conduct more experiments (Dara read student's journal)." (3rd Group meeting: Dara, Jan 10th, 2009)

The teachers and I discussed how to use this information to modify the learning activity in the next occasion. In addition, in order to assist Dara in designing the assessment tools, the teachers in the collaborative action research group discussed her lesson plan and suggested to her some questions that should be asked to assess students' understanding.

In the third cycle, Dara appeared to be trying to correlate learning assessment with the learning experiences she facilitated in the classroom. She used, three assessment methods consisting of questioning during class discussion, an individual exercise, and a group work exercise to assess students' understandings. Throughout the

variety of assessment methods, Dara felt that, up to this lesson, she had a better understanding of how to assess student's learning.

In the earlier lesson, Dara had had a problem about a lack of time to observe students working together. In this lesson she reduced some of the students' work, which gave her more time to walk around the room to observe and guide students. Even though she did not develop an evaluation form, she placed greater emphasis on observing how students worked as a group, and used what she found at hand to give students feedback.

In summary, Dara developed her understanding about assessment from analyzing and discussing assessment methods with other chemistry teachers, facilitator 2, and I. She came to understand how to assess expected learning outcomes and employed a variety of assessment methods including: observation, questioning, hands-on assessment, exercise or students' works and a test, in order to know how students progressed rather than to judge how well they understood the lesson. Furthermore, she focused more on social aspects so as to encourage students to work cooperatively.

Role of the Teacher

The Multiple Roles of Teacher

In the first semester the obvious role Dara acted out in her class was that of information provider. It was consistent with what she thought of as a teacher's role, as she mentioned in the first meeting: "I think as a teacher I have to explain the information for students." (1st Group meeting: Dara, Nov 8th, 2008)

In the first group meeting, facilitator 2 talked about a teacher role in constructivist teaching who encouraged students in thinking, and doing both minds-on and hands-on activities. As regards her teacher role, Dara tried to change her role, aiming at facilitating students' learning in her class by asking and responding to

students' questions. After teaching the concept of molecular shape, she described her role to help students in the class as below:

> Because this is the first time for students to comprehend what they have learned by themselves, they normally rely on the teacher to reach a conclusion for them. To have students practice making a conclusion, I help them by asking questions. (Interview after teaching: Dara, Dec 4th, 2008)

Even though Dara increasingly asked students, during class observation I found that Dara was concerned to cover sufficient content, and she always answered her own question if students kept quiet. This evidence indicated that Dara still played as a facilitator or a guide less and focused more on supplying content knowledge.

Even though during the group meeting Dara seldom shared her experience of her teaching, she was a good learner and listened carefully to other teachers talking about teacher's roles, in the second cycle, Dara tried to help her students achieve a better understanding of the concept taught. She developed her practice by giving students adequate examples, until she ascertained that students understood the proper ways of viewing an idea and solving a problem. She asked various questions in encouraging students about the concept being taught, until students finally arrived at their understanding. One example of how Dara facilitated students to understand the concept of molecular polarity is described below:

Dara:	Do you need more examples?
Students:	Yes, we do.
Dara:	Let's look at NH_3. What group does nitrogen belong to?
Students:	Fifth group.
Dara:	How many bonds does the fifth group have?
Students:	Three or five.
Dara:	Open your book and then search for the shape of NH_3.
Students:	Trigonal pyramidal shape.
Dara:	How can we draw this shape?

Students: There are three bonds and a lone pair of electrons.

Dara: Where does the arrow point to?

Students: Nitrogen

Dara: What is the type of nitrogen molecule, polar or non-polar?

Students: Polar molecule.

(Classroom observation: Dara, Dec 9th, 2008)

In the third cycle, Dara still played her roles similar to how she had played it in the second cycle. She first gave the simple example and model as to how to calculate the expected answer. She then presented the more complicated example. While the students were working, she kept trying to facilitate their efforts by asking questions and giving more clues.

In summary, Dara gradually changed her role from the information provider to play the multiple roles. In the first semester, she always acted as the information provider who transmitted all content knowledge, and students were asked simply to copy what she had taught. In the second semester, at the beginning, she tried to facilitate students' learning by asking more questions but she still emphasized giving content knowledge. In the second and the third cycles, she remarkably changed her role to be that of the facilitator, the motivator, or the guide by listening to students in order to understand their thinking, by questioning them so as to encourage their thinking, and by interacting with some students in order to see how they comprehended the new information or even whether they were getting confused, and by helping students formulate conclusions. In addition, in attempting to change teaching and learning for students better understandings, Dara also acted herself as a researcher to study in what way was suitable to her students learning in her classroom.

The Case of Aree

Lesson Introduction

Way of Changing Practice in Eliciting Students' Prior Knowledge

Aree was one who rarely asked for students' prior knowledge before introducing the new concept. In the previous semester, she always reviewed students' knowledge of the previous concept students had learned, and then she would tell them what she was going to teach. Aree stated in the first meeting that: "Asking about prior knowledge is asking about the previous concept that students had learned." (1st Group meeting: Aree, Nov 8th, 2008)

Even though facilitator 2 and I had explained about asking for prior knowledge, and we gave some examples in the first group meeting, nevertheless Aree still had a limited understanding of asking for prior knowledge. Before teaching the concept of units of solution concentration, Aree and I had one-on-one discussion. We talked about her lesson plan wherein she posed one question to ask for students' prior knowledge: How could we identify the quantity of solute in any solution? Beyond this question, we discussed how to formulate a question that probably linked students' everyday life with the given topic, and which would make it easier for students to think about units of concentration. After discussion, Aree revised the activities in her lesson plan and developed new questions which were used for eliciting students' prior knowledge, and consisting of the following: 1) What does it mean to have a 40% concentration of juice? 2) How do you understand about saline solution 0.5 mol/dm^3? 3) How could we identify the quantity of solute in any solution?

In the beginning, Aree had a limited understanding as to how best to elicit students' prior knowledge; however after learning from the first group meeting, Aree was able to develop questions that could ask for students' prior knowledge of the new concept.

In second meeting, Aree described the problem she faced in eliciting students' prior knowledge in the first cycle: "Even though I know how to elicit students' prior knowledge, I still do not know how to deal both with students who already understood the new concept and students who had no idea about the new concept." (2nd Group meeting: Aree, Dec 6th, 2008)

Furthermore, even though Aree was able to develop questions to elicit students' prior knowledge in the first cycle, she still was not able to develop others questions for other topics. She raised her questions in the second group meeting that:

> I really need everybody to help me whether or not the following question should be asked for eliciting students' prior knowledge regarding the concept of solution preparation. This involved a preparation of 0.4 mol/dm^3 of sodium chloride, 250 cm^3. In eliciting students' prior knowledge, I will ask them to do a class discussion about how to prepare this solution, about which method should be used. (2nd Group meeting: Aree, Dec 6th, 2008)

From Aree's questions, the group discussed how to help her formulate questions for eliciting students' prior knowledge in a simply way. Facilitator 2 clarified how to elicit students' prior knowledge and gave one example of how the teachers could use students' everyday life as a simple way to ask students, such as asking about how to prepare syrup.

After the second group meeting, Aree learned from the suggestion from facilitator 2, other teachers, and I. She developed a lesson plan that illustrated how she elicited students' prior knowledge prior to teach the concept of solution preparation. She told me while explaining her lesson plans that: "In order to ask for prior knowledge of solution preparation, I will ask if we would prepare the solution with particular concentration, how we can do it." (Interview before teaching: Aree, Dec 15th, 2008)

During class observation she used the following questions to activate students to express their understanding of how to prepare a solution: 1) If we have table salt and

we want to make a class of saline solution, how can we make it? 2) How can we prepare a saline solution for a specific concentration and volume, such as 0.4 mol/dm^3, 250 cm^3?

Similar to the first topic of this cycle, Aree increased her understanding and changed her practice to elicit students' prior knowledge before introducing the new concept. Aree could create a set of probing questions that uncovered the students' prior knowledge of the topics of the melting point and boiling point of pure solvent and solution. The questions that were developed including: 1) How does the trend of the boiling point of a solution such as glycerol in ethanol compare to the boiling point of the pure solvent of ethanol? 2) How do you think about the melting point of a solution compared to the pure solvent? 3) How does the boiling point of a solution and pure solvent compare to the melting point of a solution and pure solvent?

In the second cycle, Aree could apply her understanding, due to eliciting prior knowledge from group meeting, to her lesson plans and her teaching practice, both on the topics of solution preparation and the melting point and boiling point of pure solvents and solutions.

Similar to the second cycle, in the third cycle Aree had a good understanding of how to elicit students' prior knowledge. On the topic of chemical equations, the questions that were developed included: 1) How do you write the relationship between chemicals in a chemical reaction? 2) How do you understand the relationship between each chemical in a chemical equation?

In summary, Aree rarely elicited students' prior knowledge in the first semester and she had a limited understanding of prior knowledge. She developed her understanding after learning from the first group meeting and later discussions with me. From the first cycle to the third cycle, she was able to formulate many questions to elicit students' prior knowledge and she then linked what students understood to new learning activities.

Learning Activity

Ways of Encouraging Students' Participation in Their Learning Process

Regarding teaching method, Aree described her main method to the group, saying:

> When I asked students to conduct an experiment, I initially introduced the lab procedure but I did not asked them to designed or plan for the lab procedure. I instead asked them to read from the textbook. I sometimes used a lecture because students had never studied those concepts. (1st Group meeting: Aree, Nov 8th, 2008)

Aree thought that having students do some assignment by giving them some handouts and then having them summarize what they had studied by themselves, was one teaching method based on the constructivist approach that she also performed in her class. As described here, Aree had a limited understanding of teaching based on the constructivist approach in that that she focused only on doing hands-on activity. Similar to Dara's case, therefore facilitator 2 and I discussed how to facilitate students' construction of their understanding by having teachers strike a balance between hands-on and minds-on activities.

After the first group meeting, she developed one lesson plan on the concept of units of solution concentration. She wrote that having students respond to teacher's questions and answer into the worksheets was the way for students to take responsibility in their learning and construct their own meaning.

During class observation, Aree asked students about the definition of each unit of solution concentration, and then she explained those definitions and demonstrated how to calculate for those concentrations. Students were asked to complete some short writing assignments explaining the concentration units of given solutions as well as explaining how to calculate the concentration of each unit. Aree had students present

their answers to the class. During this activity, she asked questions, for example: 1) What does the question ask? 2) How much concentration in term of percentage by mass does this solution have? 3) Where does the five hundred come from? Students responded to these questions by explaining each step of the whole process. In the meantime, the rest of the class could compare their work with the work being presented and they were able to comment on it. When students answered incompletely, she had them revise their work.

Aree encouraged students to participate in their learning activities by having them do an exercise as well as asking them some questions. Students were free to do the assignment and they were allowed to share their works with their friends. When asking questions, Aree was not fixed on only getting the right answer, but rather she emphasized students participating in discussion and seeking their own understanding. In the first cycle, Aree changed her practice from the first semester in that she asked more questions aimed at activating students to think and to seek for their own understanding rather than simply explaining to them the information and letting them do the exercise.

Even though Aree was able to formulate several questions, she herself thought that she still had a major problem asking students. She mentioned this problem during the second group meeting: “I am not good at formulating the questions to have students engage in learning activity, so that consequently students do not pay much attention.” (2nd Group meeting: Aree, Dec 6th, 2008) From Aree’s problem, the group went on to discuss how to ask questions in each period of time in the classroom. Benja recommended that it was really important to review the previous knowledge before linking it to the new concept. Facilitator 2 suggested how to question before conducting the experiment, in that the teacher should be aware, in asking about the aim of experiment, tentative result or hypothesis, and variable, which students clearly understood what they were doing. After conducting experiment, the teacher should encourage students to arrive at a conclusion as well as to apply the knowledge from the experiment to the new situation, which was the main step in teaching based on the constructivist approach.

Beyond having a problem with formulating question, Aree also had a problem with teaching by experimental method. Aree always had students conduct an experiment following the given procedure in the textbook, as was the case in the first semester that she also mentioned in the first group meeting. In this regard, Aree had limiting understanding about encouraging students to do minds-on and hands-on activities when conducting the experiment, Aree raised her problem in the second group meeting, saying:

> I wonder if the activity I designed helps students in constructing their understanding. In my plan I will give students handouts that address the aim of the experiment and give the procedure. It seems I tell students directly how to prepare the solution. Do you have any suggestion? (2nd Group meeting: Aree, Dec 6th, 2008)

During the group discussion that focused on Aree's question, facilitator 2 explained how to formulate the questions to encourage students in thinking of preparing solution. Facilitator 2 suggested one example as an alternative approach by linking student everyday life to the main concept:

> You might primarily ask students, how they prepare lemon juice. After that you might ask students to think about how to prepare a solution in the laboratory that required a specific concentration, and about how they would prepare the solution if they had sufficient laboratory measuring instruments. This is a way to facilitate students' construction of their own understanding by having them design their own procedure. (2nd Group meeting: Facilitator 2, Dec 6th, 2008)

Learning from the second group meeting was the guidance for Aree to modify her lesson plan. She sequenced the activities by primarily activating students to think about what they were going to study, and she later allowed students to do hands-on activities. Because it was very important to review what students had already learned and then link that to the new concept, Aree therefore decided to add one learning activity: introducing the measuring instruments. With this, she aimed to help students

employ the instruments rightly, and subsequently they were able to prepare the solution correctly.

During class observation, students were asked how well they understood some instruments and their application. Aree then allowed students to try out using those instruments, with her guidance, before preparing the solution. After the students understood properly how to use the measuring instruments, Aree gave an opportunity for students to prepare solutions 0.1 mol/dm^3 of Sodium Hydroxide, 250 cm^3 and 500 cm^3 diluted Sodium Hydroxide 0.01 mol/dm^3. Before preparing solution students did a class discussion about the composition of a solution consisting of solute and solvent, how to calculate the amount of a solute and solvent using either 250 cm^3 or 500 cm^3 volumes, and how to prepare this solution. After a class discussion, and after providing clear guidance, students were allowed to do this activity based on what they planned and managed in their own group. Then they wrote the report as a way to explain how they prepared the solutions.

Another example that demonstrated that Aree also changed her practice aiming at developing students' scientific process skills was when she had students conducted an experiment to test the boiling point and melting point of various pure solvents and solutions. During class observation, Aree posed many questions in order to engage students to think about the boiling points of pure solvent and solution. She also encouraged students to set out a hypothesis, and allowed them to test a hypothesis by conducting a careful experiment. After every group was finished their work, Aree asked about their results with such questions as: What about the boiling point of alcohol and glycerol in alcohol? She reminded students about the hypothesis set out before conducting an experiment, and encouraged them to compare their results with their hypothesis, to see whether it was similar to what they had predicted. She had each group of students present their results. In case she found that some groups got results unlike those of the other groups, she discussed with them what the error was. Then she asked various questions to help them reach a conclusion: How does the boiling point between pure ethanol and a solution of glycerol in alcohol change? Finally students and Aree concluded the result together. In order to apply what students understood from the

experiments, they were asked to fill in their worksheets where it required students to reach a conclusion about the relationship between the boiling point and melting point of pure solvent and impure solvent. Students drew their own conclusions. Aree asked representative students of each group to present their own conclusions, and finally they were able to arrive at the same understanding of the main concept.

In this second cycle, Aree also used questioning during class discussion and had students doing an exercise. Aree developed her practice by encouraging students to do hands-on activities such as using of measuring instruments. She remarkably changed her practice by asking and encouraging students to set out a hypothesis and by discussing what students were going to study, rather having students doing activity following the given procedure, as was the case in the previous semester.

In the third cycle, in teaching the concept of chemical equations and calculation for the amount of substance in a chemical equation, Aree described how she developed one activity aimed at encouraging students to think about the relationship between the amounts of chemicals, rather than just teaching from the textbook:

> I used to have students conduct an experiment, but I found that the problem of data quality and the uncertainty of their analysis became important issues. Sometimes when doing an experiment, the result was not as we expected and it made students just more confused. This approach with providing the experimental data for analysis allows students to understand easily the relationship in terms of the mole of each chemical in a chemical equation. (Interview after teaching: Aree, Feb 2nd, 2009)

Aree briefly described her teaching on this lesson. At the beginning students were asked to explain the relationship between chemicals in a chemical reaction. She then encouraged them to initiate a class discussion analyzing the data of one experiment, which was the reaction between lead (II) nitrate ($Pb(NO_3)_2$) and potassium iodine (KI), consisting of five different trials of this reaction. The $Pb(NO_3)_2$ was fixed with the constant volume in each trial and KI was varied. The following questions were

raised by Aree: 1) Which trial, that the reactants were equally reacted, meant no more of either $Pb(NO_3)_2$ or KI left after the reaction taken place? 2) How do you draw a chemical equation to represent this reaction? 3). How much mole of $Pb(NO_3)_2$ was used in the fourth trail ? Students responded to those questions. They finally were able to answer and to indicate the balanced amount of chemicals used in the reaction in terms of mole after they had analyzed the data and carried out a class discussion.

As mentioned above, the data analysis was one activity in which students had an opportunity to analyze data without conducting a real experiment. This activity enabled students to develop thinking skills. In another activity in this lesson, Aree allowed students to undertake solving stoichiometry problems. The questions required students to find out the quantity of reactants used and the products produced of particular reactions by determining the ratio of the amount of reactants (in mol) used and products produced from a chemical equation. The class had a short discussion, and then they were asked to present their answers to the class. Aree helped them explain by asking questions and added in the missing points.

In summary, in order to encourage students to participate in learning activity and have some responsibility in their learning activities, Aree used three main approaches: questioning during class discussion, having students do the given exercise, and hands-on activity. She changed her practice in that she increasingly emphasized questioning rather using lectures, as had been the case in the previous semester. As regards doing hands-on activity, which mainly took place in the second cycle, she developed her understanding in engaging students to think of what they were studying rather than telling what students had to do and emphasizing only hands-on activity. As regards doing the exercise, Aree had developed the exercise suitable for class activity, by means of which students could practice what they had learned as well as develop their thinking skills.

Social Interaction in Classroom

Journeys to Incorporate Cooperative Group Learning into the Classroom

In the first group meeting, Aree had learned about the feature of cooperative learning suggested by both myself and facilitator 2. Aree acknowledged that learning should involve cooperative learning, and she then incorporated group learning in her lesson plan. She reorganized students into groups smaller than those in the previous semester, aiming at having students learn together by allowing them to work more closely together. Before teaching the concept of units of solution concentration, Aree and I discussed about applying the Jigsaw technique to encourage cooperative learning in her class. However due to lack of time to prepare instructional materials, and lack of time for doing the activity, she decided to have students only do pair work in their own group.

In her class, after she guided students regarding units of solution concentration, she then distributed worksheets and encouraged students to work as a group, saying:

> You have your group consisting of four students. So you can help each other think together. One may read the handout and others may think about it or ask questions . . . you probably study together and the one who is an expert can explain matters to other members in your group. On the other hand, you can also do the exercise firstly in pairs. After you are finished you can discuss your work with another pair of your group, whether or not your work is corrected. (Classroom observation: Aree, Dec 1st, 2008)

After allowing students to work in their groups, she described what she observed to me:

> It didn't seem obvious that cooperative work had taken place in my class. Students generally worked individually if they could solve the problem presented. Probably I did not tell them clearly enough how to work as a group.

> The students probably think they need not work together because they could keep doing their work without any help. (Interview after teaching: Aree, Dec 1st, 2008)

In the first cycle Aree developed activities and instructional materials that enabled students to do group work but she still struggled to encourage students to engage in effective group activity.

In the second group meeting Aree raised her problem to the teacher group, saying: "I had some problem with cooperative learning. I asked them to brain storm in doing the exercise, but I found that they still worked individually. I thought that was because I probably did not give a clear suggestion on how to do group work." (2nd Group meeting: Aree, Dec 6th, 2008).

Similar to other teachers faced with the problem of how to apply cooperative learning in their classroom and of how to encourage students to participate in group work, facilitator 2 suggested some models of cooperative learning such as LT, STAD, Jigsaw, or Co-Co that teachers could select and apply in their class. Again, facilitator 2 also restated information about students' roles and their duties while working in groups, information which teacher should emphasize and clearly explain to students. In addition, the teachers learned together how to incorporate group work in their class by using Aree's lesson plan in teaching the concept of solution preparation as a case study. By this activity, they discussed how to group students, the sequence of group activity, and the role of students while participating in group work.

In the second cycle, Aree placed more emphasis on the students' roles in informing the aim of cooperative learning. She fully expected that students would clearly understand their duty in particular tasks in group work: "one would take the instruments, another would take chemicals, and another would record what they observed." (Interview before teaching: Aree, Nov 28th, 2008) She expressed her ideas to encourage students to work cooperatively thus:

> Another way to promote cooperative group participation in this activity is to tell students before doing the experiment that they all have to understand clearly the procedure, and that when I ask someone in their groups they have to explain to me what they are going to do. (Interview before teaching: Aree, Nov 28th, 2008)

As regards the importance of the students' role, Aree wrote in her lesson plan about the concept of boiling point and melting point of pure solvent and solution that each group members had to have their specific duty but everybody had to observe, record, analyze the experimental result together. One example of group work that took place in the second cycle involved students working on an experiment about the boiling and melting points of pure solvent and solution. A group of five students was working right in front of me. They had a stand, lamp, and beaker containing water, and a thermometer. One went to the teacher's table to get the chemicals. While setting up the instruments they talked to each other, saying for example, what are we going to (observe)? One student responded that they were going to observe the bubbles coming from the capillary. The roles of each member were exposed explicitly, in that some of them stirred the water, and some wrote the lab report. In the meantime every one kept their eyes on the test tube to observe the change taking place. In this process, the students communicated with each other, shared their ideas, worked together, and discussed, in order to arrive at the same understanding.

In the second cycle, Aree changed her practice to support cooperative learning activity in her classroom. She prepared instructional materials and learning activities that encouraged group work. Even though she planned to tell students about their roles and duties when they were working in a group, she in fact did not do that in practice. However she allowed them to manage their own group, and she herself walked around to observe how well they worked together.

In the third cycle, Aree also addressed cooperative learning as one aim of the learning activity in the chemical equations lesson. The group discussion and group work were also emphasized in the class. As Dara mentioned in the third group meeting, she encouraged students to compete with other groups, something that activated student

enthusiasm in doing group work. To adopt the idea of teaching the concept of chemical equation, Dara found competition was one approach to promote group work. Furthermore, what had changed from the previous cycles was that Aree now reorganized the members of each group after Aree got feedback about group activity from students. She grouped students into new groups using the mid-term achievement as the criteria to group students, aiming for a balance of high, middle, and low learning capability students to ensure that it was an effective learning experience for students in their groups. Subsequently, students had an opportunity to interact and to become tolerant of diverse viewpoints, to consider others' thoughts and feelings in depth, and to seek more support and clarification of others' positions.

In summary, Aree tried to build in as many collaborative opportunities for group work as possible, including dividing students into small groups that facilitated discussion while working on tasks, suggesting to students how to work in groups, and sometimes using competition among groups. In addition Aree opened her mind to share with students their points of view of learning through cooperative activity, and used students' feedback to develop teaching and learning activity.

Learning Assessment

Students' Learning and a Variety of Learning Assessment Methods

During the first group meeting, Aree did not share how she assessed her students, but she learned how to assess students learning from suggestions by facilitator 2 and I. We emphasized assessing students in each period of time, simultaneously with teaching, and aiming to understand how well students understand the concept and how they progress. In addition, I also introduced other assessment tools as the means to assess other aspects such as habits of mind, and cooperative group learning. In the first cycle, Aree developed and used various assessment methods through a number of assessment tools. Prior to teaching new information, she used questioning, group discussion, and classroom discussion as assessment methods to seek for students prior knowledge about solution and concentration. During the learning process, she used

classroom discussion and students' exercises to assess how students understood the lesson. At the end of the learning process, she used a quiz in the form of a multiple choice test to assess students' understanding of solution concentration. However, in various assessment methods she placed emphasis only on the cognitive aspect, with assessment tools specifically designed for this purpose. The other aspects, such as the social dimension or habits of mind, did not receive much assessment from her.

In the first cycle, Aree used a variety of assessment methods, and she increasingly used questioning to assess students' understanding during learning activity. But Aree still wondered how to assess students in other dimension of learning.

In the second group meeting, Aree presented her assessment tools, including: written questions quiz, and a scientific process skill assessment form adopted from the IPST. She asked the members in the group meeting if her assessment tools were suitable. In addition, because Aree had questioned me before the second meeting about assessing students' habits of mind and group work interaction, I therefore presented some assessment tools such as a habits of mind assessment form and group work form to the teachers' group as an example that teachers could adopt in assessing their students.

In the second cycle, Aree still used questioning, discussion, and students' exercises, as she had in the first cycle. She also emphasized observation to assess students' skills on using measuring instruments and conducting experiments. During class observation in teaching the concept of solution concentration, Aree always walked around the classroom and she observed how well students were working on their tasks as a group. What she observed was used to help students employ measuring instruments and conduct experiments correctly as well as to encourage students to work cooperatively. Beyond students' performances in their experiments, students' reports and presentation were also drawn upon to measure students' understanding of what they had studied. In addition, in order to assess whether individual students actually understood what they had learned, she developed quizzes which were in written format rather than the multiple-choice type that she had used in the previous semester and lesson. The quiz on the topic of solution preparation required students to explain how to

prepare a solution in a particular concentration. One set of this quiz contained five questions. The tests would be distributed to each group. Each student could pick only one question. Therefore nobody received the same question. However in fact, this quiz was not used due to lack of time.

In this cycle, it was not just the teacher who acted as a main assessor; students were also empowered to assess the teaching and learning activities. Students' journals and interviews were used as assessment tools. Aree assigned students to write journals; she adopted the journal form from the first meeting, presented by myself. She also used informal interviews to ask her students to expound their ideas, after she received students' journals. After she got feedback from students both from journals and interview, she told me that two main problems emerged from her teaching practice. First some students thought the group work could not help them much because some members of the same group did not understand some concepts they were studying. Second, students still preferred to be fed information or explanation but they did not like to be asked questions since they felt that pressure was put on them.

In the third cycle, similar to the first two cycles, she used questioning during class discussion, students' worksheet answers, and observation to assess both students' understanding and their social skills.

In summary, Aree used various types of assessment methods. The assessment methods included: questioning, students' works which included exercises and reports, observation, and quizzes. In the first semester, Aree emphasized only conceptual understanding as her students' learning outcomes and mainly used quiz and test to assess students' understanding. In the first cycle, she used a variety of assessment methods, to assess students' conceptual understanding in each period of time. In the second and the third cycle, Aree developed her understanding of assessment and came to understand more about objectives in learning for each lesson and how to assess expected learning outcomes. She focused more on formulating a quiz that could assess actual students' understanding, which required students to explain what they understood, and demonstrate reasoning. Aree placed more emphasis on assessing

students' understanding during learning activities, and used what she found to help students to learn better. Aree focused more on the social dimension of students' learning as learning outcomes in the lesson. Furthermore, students were allowed to share their ideas freely through writing students' journals and in informal interviews, on what they thought about learning activities. Students' feedback was used as a part of learning activities development in the classroom.

Roles of the Teacher

The Multiple Roles of Teacher

> Teachers as facilitators, in my view, have to give suggestions so as to help students take the right approach to studying. I mean they could design learning activities and produce some handouts as guidance for students to learn by their own way. Students had to practice and to summarize by themselves in order to help construct their own understanding. (1st Group meeting: Aree, Nov 8th, 2008)

In the beginning, Aree had a limited understanding about the teacher as a facilitator, a position which was similar to that of Dara. After discussion of the roles of the teacher in the first group meeting**,** Aree tried to change her role by increasing her role as a facilitator, a guide, or a motivator, and reducing her role as information provider. During class observation, she posed questions and then guided students to motivate them find their own answers. She also suggested how to answer and allowed students to ask questions. In order to conclude the lesson, she asked students to present their answers to the class, and she added more explanation so as to fill in the missing points.

Aree developed a new way of teaching by posing more open ended questions, providing instructional materials, encouraging students to initiate a classroom discussion and giving students' an opportunity to revise their work in order to improve their learning.

As regards facilitating students' learning activity, Aree expressed in the second meeting how she changed her roles:

> I previously did not emphasize enough the need to help students construct their understanding. I just explained the information and then let them to do an exercise. In the new practice based on the constructivist approach when I designed lesson plan I kept thinking how I could help students in constructing their own understanding. (2^{nd} Group meeting: Aree, Dec 6^{th}, 2008)

However, Aree still wondered what kind of questions she could pose to help students attain understanding. In order to assist the teachers in their roles, Facilitator 2 used role playing as a way to introduce the teacher's roles as a facilitator in teaching solution preparation:

> Facilitator 2: Could you tell me what you understand about concentration?
> Aree: Students have already learned about units of concentration. Thus, when asked about concentration such as 0.4 mol/dm^3 of NaCl, they would answer there was 0.4 mol of NaCl in 1 dm^3.
> Facilitator 2: How can you calculate for mol?
> Aree: It comes from formula mass.
> Facilitator 2: Could you tell me again how you calculate for mol?
> Aree It is calculated from mass in terms of gram unit divided by mass of empirical formula. Because sodium chloride is an ionic compound, therefore we have to calculate by using its empirical formula mass.
>
> (2^{nd} Group meeting: Dec 6^{th}, 2008)

From the conversation in which Facilitator 2 acted as the teacher and Aree acted as student, Facilitator 2 aimed to assist the teachers to see a concrete example of how a teacher could encourage students in thinking and answering, which was one practice of the teacher as a facilitator.

After the meeting, Aree tried to change her roles so as to facilitate student learning. Aree walked around the room, rotated from group to group and had interaction with students. To foster discussion with students in the classroom, she asked questions until students arrived at an understanding of the process they were going to do or had just concluded.

One example, after teaching the concept of solution preparation, Aree described her role how she facilitated and motivated students in learning that in general she used questioning in the class to encourage students to think in giving her answer or explanation. She let them work on their tasks first, and if they were not able to do so she had them work with their friends. However, if they did not understand the procedure or did not know how to begin, she explained the important points for them and had them revise their work. Finally she explained and corrected their work again. She further stated that she actually would like them to think by continuing to ask questions. On the contrary, she thought that if she did not ask them, but rather simply told them the main concept or gave them the answer required, that would probably made students overly dependent, waiting on the teacher to give them the right answer.

In the third cycle, acted with a multiple roles, Aree walked around the classroom and asked questions to prompt students to think about their tasks, and at the same time she provided suggestions to those who were struggling, and also checked on quiet students. Similar to the previous cycle, she also gave everyone an opportunity to express opinions, responded to those opinions, and maintained open communication. She also helped students to conclude the lesson and filled in the missing points. In addition, throughout the three cycles, Aree acted as a researcher who was trying to use new method in teaching aiming to help students' learning.

In summary, Aree gradually developed her multiple roles as a facilitator, a guide, and a motivator in the meantime a teacher as a researcher to search for better learning for her students. In the first semester it was obvious that she placed most emphasis on what students should learn based on the notion that the teacher was more a provider and less a facilitator. After sharing her point of view in the second meeting,

she obviously developed learning activities allowing students to participate more in their learning activities. She encouraged students to take responsibility for and think about what they were studying. In addition, she also used what she found from students' feedback to develop teaching and learning activities.

The Case of Benja

Lesson Introduction

Way of Changing Practice in Eliciting Students' Prior Knowledge

Regarding her understanding of prior knowledge, Benja stated in the first group meeting: "I would ask for prior knowledge (to introduce the new concept). I primarily think when I ask about prior knowledge that I would probably get either the right or the wrong answer (but I do not know what it is)." (1st Group meeting: Benja, Nov 8th, 2008)

Even though in the first semester Benja always sought students' prior knowledge before introducing the new concept she was teaching, as mentioned in the first group meeting she demonstrated that she still had a limited understanding of just what prior knowledge was. Her response as to how and why one should elicit students' prior knowledge was unclear. After I talked about how to elicit students' prior knowledge, I had all teachers analyze the Benja's teaching practice as to how she asked her students about their prior knowledge as regards the concept of the gas ratio in a chemical reaction. In this activity, the teachers discussed and analyzed her practice. Benja herself answered that she also asked for students' prior knowledge, but she still did not respond clearly as to what questions she asked to elicit that prior knowledge. Therefore I explained to all teachers what question should be asked as regards this concept, thereby aiming to have all teachers achieve the same understanding in the matter of asking for prior knowledge.

In the first lesson, Benja adopted what she understood from the first group meeting and she designed her lesson plan in the concepts of chemical equilibrium accordingly. During class observation, the following questions were asked for eliciting students' prior knowledge about chemical equilibrium: 1) Does the chemical reaction have an equilibrium state? 2) How can we prove a chemical equilibrium state in a system? 3) Is the reaction still taking place at the equilibrium state, and why? Furthermore, Benja emphasized that this previous knowledge was able to help students simply by linking what they understood to the new concept.

In the second group meetings, Benja did not mention how she elicited students' prior knowledge in her previous lesson, but she did talk about how she reviewed students knowledge of previous concepts, and that this could facilitate students' ability to learn the new concept.

In the second cycle, as learned from both group meetings, Benja had a quite clear understanding of eliciting students' prior knowledge. During class observation regarding the concept of equilibrium constant, Benja introduced her lesson by presenting the data of the reaction between hydrogen gas (H_2) and crystal of iodine (I_2) which produced hydrogen iodine (HI), and then she asked for the quantitative relationship between the concentrations of reactants and products at the equilibrium state.

Even though Benja demonstrated that she had a quite good understanding of eliciting prior knowledge prior to introducing the new concept, in the third group meeting, she raised her questions which demonstrated her continuing confusion between asking for prior knowledge and questioning in assessing students understanding what they already had learned, saying: "I think that prior knowledge probably is asked for after teaching. For example, we could ask (about equilibrium) in application of this concept to explain the new situation. Is prior knowledge asked after teaching? Am I right?" (3rd Group meeting: Benja, Jan 10th, 2009)

These demonstrate Benja's limited understanding about assessing students' understanding of the concept when she had completed teaching. It was in this meeting

that I first detected her confusion between assessing students' prior knowledge before teaching and assessing students' understanding of the concept they just had learned. Therefore I explained to her that asking prior knowledge aiming to assess students' understanding while they were learning the concept that they will learn. On the other hand, we could assess students how they constructed their understanding by asking after they were completed learning that concept, for example, we could ask students to explain the new situation by using that concept.

Even though Benja demonstrated a bit of confusion about asking for prior knowledge and assessing students understanding, yet in the third cycle she could explain confidently the kind of questions that related to the new concept and which should be asked before teaching. For example Benja mentioned as regards eliciting students' prior knowledge in the topic of electrolysis of acid-base solutions:

> In today's class, the main point is whether or not acid and base are electrolytes and are in an equilibrium state. Students did not know yet whether or not the weak acid and base were in an equilibrium state. Therefore I could ask this question in eliciting students' prior knowledge. (Interview after teaching: Benja, Jan 30th, 2009)

During class observation, Benja began the lesson on the concept of acid and base by reviewing the previous concept learned. She then asked about students' prior knowledge as to what linked acidic and base electrolysis to chemical equilibrium. The following questions were asked: 1) Did you consider whether or not acid and base were in equilibrium? 2) Which type of acid or base was in equilibrium? 3) How much concentration of each ion was there in acid or base? 4) What could we do to find the concentration of each ion in the acid or base? After that, students began a class discussion.

In summary, Benja understood quite well how to elicit students' prior knowledge, even though she was a bit confused in asking how to apply the new concept. What she developed from the previous semester was greater attention to students'

answers. She used those answers in classroom discussion so as to engage more students in learning. Besides the fact that she could formulate questions and ask for students' prior knowledge, Benja also gained sufficient confidence to explain what questions were suitable to ask for eliciting student's prior knowledge.

Learning Activity

Ways of Encouraging Students' Participation in Their Learning Process

In the first group meeting, Benja mentioned that she used various teaching methods including questioning, class discussion, and sometimes using lecture and experiment. In her understanding, she thought that her teaching was relevant to constructivist-based teaching:

> I think I always have used the inquiry approach and I ask a lot of questions. (In my opinions teaching based on the constructivist approach) is teaching by using the inquiry approach. The inquiry approach in my practice means using questioning. (1st Group meeting: Benja, Nov 8th, 2008)

As Benja indicated above, she had a limited understanding of teaching based on the constructivist approach in that she believed that questioning was the main teaching method. Furthermore, when asking other teachers to reflect on Benja's teaching, Aree remarked that even though Benja asked a lot of questions when teaching, she did not ask clearly to encourage students to formulate the hypothesis before conducting the experiment. Similar to facilitator 2, she thought that Benja focused only on hands-on activity and put less emphasis on minds-on activities. As well, Aree thought that Benja failed to ask about the aim of the experiment, and did not clearly discuss the experimental procedure. These reflections from Aree and facilitator 2 revealed that Benja still had a poor understanding as to how to encourage students to undertake minds-on activities aimed at developing students' thinking skills. As mentioned earlier about teaching activities in the first two cases, Benja learned from facilitator 2 and me

how to ask questions and design learning activities aimed at supporting both hands-on and minds-on activities.

In the first cycle, teaching the concept of chemical equilibrium, Benja used four teaching approaches, consisting of questioning, explaining, class discussion, and experiment. She described the way she helped students construct their understanding of the topic as follows:

> What I did for today's class to help students elaborate their own understanding was questioning, encouraging students to participate in a class discussion, explaining a new conception, and allowing students to conduct an experiment. All those activities were designed to prompt students to think, to analyze, and to link the main concepts from phase equilibrium and saturated solution equilibrium to chemical equilibrium. (Interview after teaching: Benja, Nov 21st, 2008)

For example, before introducing the new concept about chemical equilibrium, Benja asked her students several questions in order to prompt them to think about what they were going to study:

Benja:	How do we know that the reaction between A and B is in an equilibrium state?
Students:	There are changes to both sides of the equation; forward and backward.
Benja:	What about of the reaction rate of both the forward and backward parts?
Students:	They are equal.
Benja:	Why do we still find the reactants after the reaction has taken place? Where do the reactants come from?
Students:	They come from the reverse reaction. The products of the forward reaction behave as reactants of the reverse reaction. The

> reaction is reversed and the reactants of the forward reaction are produced.
>
> (Classroom observation: Benja, Nov 21st, 2008)

Benja further asked students that if they had a new reaction to study, how could they test whether or not that reaction was a reversible reaction and in equilibrium. Benja asked students about the aims of the experiment and then explained the lab procedure as suggested in the chemistry textbook. However Benja did not ask students to formulate the hypothesis, to identify the variables of the experiment, and to design a data table. After Benja explained the procedure, students were allowed to conduct the experiment immediately because the class time was almost at an end. During the experiment, Students discussed what they had observed and then recorded it into the data table.

After students had finished their experiment, the class discussion took place. Benja began to discuss about the aim of the experiment, hypothesis, and variables, and after that students were asked to present their result. Because Benja did not discuss how to record the data and create a data table, when students presented the results in their own table, there was not sufficient information to establish a conclusion. Benja then erased that table and drew her own table, and asked for the result from students. Then the experimental result was discussed to finally conclude the experiment. After Benja had finished teaching, I talked to her about encouraging students in conducting the experiment that in planning to conduct the experiment, I thought Benja had students read from the book as to what students had to do. Rather, students should be allowed to work together in planning what they were to study. As I observed of Benja's practice, I found that students did not understand, and as a result students still followed the textbook. In addition, we also discussed how she handled class discussion before and after conducting the experiment. In our discussion, I encouraged Benja to be more aware of the need to clarify what students were studying.

In this first cycle, Benja tried to encourage student participation in their own learning activity, which focused on challenging students to prove the equilibrium of

chemical reactions through an experiment. She developed various questions to prompt students to think and to discuss before conducting the experiment. However she did not allow students to plan their own procedure in their respective groups. What she developed from the previous semester was the need to discuss the aim and experimental procedure so as to help students understand what they were going to study. But Benja allowed students to conduct the experiment without clearly identifying the hypothesis and variables of the experiment, just as she had done in the previous semester. Due to lack of time, Benja did not focus on assessing how well all students understood what they were going to study. She left students with insufficient time to plan and manage their own procedure in their respective groups.

In the second group meeting, as regards conducting the experiment, Aree raised questions about how to initiate a discussion before the experiment that would facilitate student thinking about it. Facilitator 2 suggested one approach that teacher first asked students about the aim of the experiment, about the hypothesis, or any of the variables. After students had expressed their thought, teachers then should discuss with students again what they were studying and let them write their remarks on the worksheet in order to be sure that students had the same understanding of what they were studying. As well, it could help them to remember while they were on task. After facilitator 2's explanation, I encouraged Benja to describe what she did when having students do the experiment. Benja replied:

> Before conducting the experiment, I talked about what we were studying, and about the aim of the experiment. Then I would ask what would be taken place or changed, this question was asked aiming to formulate the hypothesis . . . I asked them what we could do (for the test). After finishing conducting the experiment, I would give them a work sheet and then I discussed and had them write about the hypothesis and variables together. Otherwise, they would identify the variables incorrectly . . . however I believed that my students understood about aim, hypothesis, and variables before conducting the experiment . . . Actually, I accepted facilitator 2's suggestion that we should

have a worksheet to discuss with students what they were studying, but I did not do that. (2nd Group meeting: Benja, Dec 6th, 2008)

Benja's comments revealed that she only used oral questioning during a class discussion and she was not aware if all students understood for what they were studying. Even I suggested that the crucial point was that the teacher had to be sure all students understood clearly what they were studying, and Facilitator 2 also repeatedly stressed this aspect, Benja still held her belief and practices based on her belief.

However, in the second cycle, there was no topic to teach by using an experiment. In teaching the concept of equilibrium constant, Benja planned to use a class discussion, an exercise, and group sharing, as the means to help students in the construction of their own understanding. She developed various questions, and encouraged students to explain what they understood. In addition, to allow students to apply the knowledge they had learned, Benja developed worksheets and keys to help students apply and check their own results. During classroom observation, students were allowed to discuss in their groups in order to be clear about the whole process. In order to be sure that students had participated fruitfully in their own learning, Benja asked the representatives of each group to explain the process of solving the given problem to the class. In this activity, Benja also asked questions aimed at assessing the students' findings, for example: 1) What is the question asking for? 2) What is the equilibrium constant of this reaction? 3) How can you write the relationship among the concentrations of each particle or ion in this reaction? Then, the students responded to each question and they explained the steps in finding the answer.

In the second cycle, Benja obviously changed her practice from the first semester. She did produce instructional materials and she allowed all students to study on their own, rather than only asking some students and having students study only from the textbook, as she had in the first semester.

Even though in the second cycle, Benja did not teach by using experiments, she still wondered about how to encourage students to conduct the experiment. In the third

group meeting, Benja brought along her lesson plan on the concept of chemical equilibrium that she re-wrote after she had learned to do so from the previous meeting. However, in Benja's presentation, I just first found her confusion about asking for conducting a hypothesis as she said: "I think that asking about prior knowledge is asking for conducting a hypothesis that demonstrates how students thought" (3rd Group meeting: Benja, Jan 10th, 2009). As she said, I clarified to her that we should first ask about prior knowledge so as to grasp how students understood the concept before we teach it to them. In case we conducted the experiment, we had to discuss with students and make clear to them aim of what they were going to study. Then we had to encourage them to formulate a tentative answer or hypothesis.

In the third cycle, Benja did not changed much about her teaching method in that she still used explanation, questioning, and an exercise. She learned from the second cycle how to balance between the teacher's explanations or questioning and giving students the opportunity to do the exercise. Students were allowed to practice and could study themselves from the key which gave more detail about how to solve the problem. She described one activity in her class as follows:

> Concerning teaching acid-base electrolysis, I explained step by step to the students, had them do the exercise, and finally had them check their answers from the key created by myself. By this method they could learn, think, and take notes after reading the key and discussing with their friends. (Interview after teaching: Benja, Jan 30th, 2009)

In summary, Benja used various approaches to engage students in their own learning process, and thereby she gave students an opportunity to assume some responsibility for the results of their efforts. In the first cycle, she emphasized having students do hands-on and minds-on activities by conducting experiments. She discussed what students were going to study and she had students do the whole process based on their plan, and allowed them to manage the process in their groups. However she still was struggling in terms of discussion that came before conducting the experiment. In the second and third cycle, she focused on helping students to reach an understanding

through doing the exercise and participating in group discussion. She developed her practice by clearly informing students about what they were going to do, and produced handouts which helped them take an active part in their own learning.

Social Interaction in Classroom

Journeys to Incorporate Cooperative Group Learning into the Classroom

During discussion in group meeting, I asked Benja to reflect on her practice whether or not the practice supported to cooperative learning in her classroom. Benja expressed her view to the group, saying: "I certainly have students working together cooperatively. When planning and designing the lab procedure, I ask them to work in pairs, to think and work together." (1st Group meeting: Benja, Nov 8th, 2008) However, I also asked other teachers to comment on Benja's practice that all teachers watched from video presentation. Aree commented on Benja's practice by saying: "I do not think there is much group work in Benja's class. Students just respond to the teacher's questions. They rarely think together. As I see it, only some students express what they are thinking." (1st Group meeting: Aree, Nov 8th, 2008)

As the excerpts above show, even though Benja thought her practice supported cooperative learning, reflections from others such as Aree revealed that Benja still did not incorporate cooperative learning in her classroom. Therefore in order to help Benja understood clearly about cooperative learning, facilitator 2 and I explained and gave the example of cooperative learning as mentioned earlier in the case of Dara and Aree.

In the first cycle, students were organized into groups of five students and then they were assigned to work together. Benja planned to have students work cooperatively in planning and conducting the experiment investigating equilibrium systems of chemical reactions. However, this activity was modified in using micro-scale methods because of a classroom condition of no running water and sinks that made it difficult to clean experimental instruments. During classroom observation, after a discussion about the experimental procedure, Benja immediately asked students

to begin their experiment without introducing students' roles or giving them time to plan their work together. Students initially studied the given procedure from the textbook. However, because of using micro-scale methods, only two or three students could access the instruments and conduct the experiment, while the others still waited at their table to write some part of the report and draw up the data table. After the class, Benja and I discussed what we found in her class. Benja described the problem she faced as regards group work in her class as follows: "Actually I knew there should be a leader, a leader assistant, and a secretary to record the result. In practice, I just asked students to carry on in their group without telling them what the role of each member should be." (Interview after teaching: Benja, Nov 21st, 2008)

As above, I also agreed to her that she did not emphasize student roles enough. As she mentioned, it revealed that she still did not understand clearly about students' roles. Therefore, I talked with her and gave examples of what the roles and duties of students in their groups should be. For example, when students were conducting the experiment, one student might design the data table, another student might record the data and so on.

Furthermore, other activities such as the discussion or exercise were not designed for group work. Benja mentioned her problem about asking students' questions and encouraging them to work as a group:

> I actually know from what facilitator 2 said that many teachers always have students sitting together as a group, but most of them still have students working individually. But for now I don't know how I can start asking students questions and let them discuss as a group. (Interview after teaching: Benja, Dec 8th, 2008)

However, even though she gave little opportunity for students to share their ideas in this class, she thought she had changed her practice from the previous semester:

> As regards group activity, I gave students the opportunity for a short time to share their ideas together, even though we did not have much time. However, I thought I had students share with their peers more than was the case in the previous semester, when I seldom had students talk together. (Interview after teaching, Benja, Dec 8th, 2008)

In the first cycle, Benja designed activities for students to work as a group by having students conduct group experiment but she still did not inform them clearly about their roles. Furthermore, she still struggled to design activities which encouraged students to work together beyond simply conducting an experiment. However, she changed her practice from the previous semester in attempting to have students working together.

In the second group meeting, as was the case with the other two teachers, Benja raised her problem about group work in her class to the member of group meeting, saying:

> I used a small scale technique so that each group got only one plate; that was one reason why they could not divide up their work. I actually planned to ask students to divide up their work so that each member would have to take some responsibility for their work. I myself also forgot to sufficiently emphasize group work. Therefore students did not work cooperatively as much as I expected. (2nd Group meeting: Benja, Dec 6th, 2008)

Because all teachers were not able to incorporate cooperative learning into their classroom effectively, facilitator 2 suggested some techniques of cooperative learning such as, Jigsaw or STAD, and she explained about student roles in group work to teachers as I mentioned already in Aree's case. Benja also suggested one technique to support students' interaction in their group. One student could answer even though it was incomplete; other students were encouraged to add more explanation until they could answer completely and collectively. Furthermore, facilitator 2 also suggested that there were two main student roles: the specific role of each student such as data

collector, manager, recorder, cleaner, and reporter; and the general role for all students that they all had to work on those tasks together.

In the second cycle, in an attempting to incorporate cooperative learning, and before teaching the concept of equilibrium constant, Benja and I talked together. It became clear that she was more aware of students' cooperative learning, saying:

> I think the main principle of cooperative learning is that all students have to work together, aiming at the group accomplishment. Therefore I create group activities in which there are two pairs in one group, and that each pair has to work. When they are finished, all members of a group then talk and correct their work from the key, until all members understand the main concept. I will pick only one work sheet from the group as representative of their efforts. (Interview before teaching: Benja, 12th, Dec, 2008)

I talked to her that she would be clear what she meant by group work since she asked only two students to do pair work. To be sure if they work cooperatively, I suggested that, after allowing students to discuss and arrive at the results, she should randomly select one member of their group to explain their work as a class presentation. During class observation, Benja had students doing the exercise in activity I about the equilibrium constant (K). After students were finished their work, she distributed the key and students could check their answers and discuss them in their groups. Benja asked students to send her only one piece of their work, which was the highest scored piece of work. However she found that there was one mistake in organizing this group activity, saying: "What I forgot to tell students was the aims of this group work, and their respective roles in it." (Interview after teaching: Benja, Dec 15th, 2008)

In this discussion, I also suggested to her ways to encourage students' group work, such as telling students that she would random select only one piece of work from them, either of the highest or lowest score, so that all members had to work together and try to reach the highest score.

In exercise II on the lesson equilibrium constant, Benja changed her practice in that she clearly informed the group about the work process and students' roles in it before having students do group work:

> Two members are paired up and work together. When you are finished you have to select one member to be a coordinator to read the answer from the given key. While you correct the answer, you have to discuss about the answers and the main idea of the exercise, in order to arrive at the same understanding. I will randomly select one of your works as representative of each group. Therefore the score of your group will depend on the work picked. Thus all members have to help each other in order to get the highest score. In addition the representative one has to be able to present to the class. (Classroom observation: Benja, Dec 19th, 2008)

In the second cycle, Benja obviously changed her practice due an awareness of students' roles and the procedure in group work. She could organize and produce instructional materials to support group work, rather than asking students to simply talk to their friends, as she had done in the previous semester or in the first cycle.

In the third group meeting, Benja presented her lesson plan for teaching the concept of chemical equilibrium, which she had re-written after she had learned more about group work and students' roles. She explained how she identified each student's role, and in the meantime she asked the members of cooperative action research group to consider whether she now understood the procedure correctly:

Benja: In my plan, the first student has to design the experimental procedure. He/she has to explain to the other members how many steps they are doing. The second student has to control or inspect whether other members conduct the experiment according to the right procedure. The third one takes responsibility for presentation of the results.

I: What I see in your lesson plan is that you have one student record data. Actually they have to record together, don't they?

Aree: If you explain like this, it seems they work individually.

Benja: Actually, they all work together. As written in lesson plan I mean they are the head of each task, such as head of data recording.

(3rd Group meeting: Benja, Jan 10th, 2009)

As our conversation above indicates, we accepted Benja's idea but in the mean time we tried to discuss about having all teachers understand clearly students' specific roles as well as the general role that all students had to assure together.

In the third cycle, there were no experimental activities, so the main teaching methods that Benja used were explanation and an exercise. Benja still used the same method used in the second cycle, allowing students to work as a group. During classroom observation, students were sharing with each other as they did before. Benja described what occurred when students were working at their tasks: "Students helped and shared with each other. They obviously did not talk much but they did see their peers' work and they shared their ideas. When they deleted or cut something out of their work, they would explain the reason to other students." (Interview after teaching: Benja, Jan 30th, 2009).

In summary, Benja now really emphasized cooperative learning. She designed activities and developed instruction materials to support this kind of learning rather than simply having students do individual work or engaging in only a brief discussion, as in the first semester. However, initially, in the first cycle she had difficulty designing group work. Furthermore, she did not understand about student roles. After sharing her problem and learning from other teachers in the second group meeting, she gradually developed her practice in the second and third cycle by designing activities to allow students to work as a group. She always analyzed her practice to identify past mistakes, and then used what she had learned to develop her practice by, for example clearly informing students about the aims of group work, identifying students' roles, and explaining the required procedure when doing group work.

Learning Assessment

Students' Learning and a Variety of Learning Assessment Methods

After learning about assessing students' learning in the first group meeting, Benja planned and used four main assessment methods, consisting of questioning, observation, exercise, and student's reports. She described how she used each assessment method for different purposes:

> In conducting an experiment, I observed how they worked with their peers, and whether or not they were cooperating and planning together in harmony. I also assessed them by asking them for an explanation of what they were studying. Regarding students' understanding of the concept, I assessed student's understanding by asking some of them in the class to get some sense of how they understood the concept even though, by this method, I still do not actually know how all students understand. (Interview after teaching: Benja, Nov 21st, 2008)

When Benja talked about the learning assessment method used, I suggested to her to ask students to write a journal, as it could help her to get feedback about the activity, rather than basing all feedback only on her own observation. In addition, I also commented that her quizzes lacked criteria to assess how well students understood the concept. However, at this time we did not pay attention to this aspect since Benja needed time to study her quizzes again. However, in practice, after finishing this lesson, because of lack of time, Benja did not assess student learning by using quizzes.

In the first cycle, Benja used various assessment methods to assess students' learning generally in each period of time, but she still did not develop the appropriate tools to assess individual student understanding and need.

After learning from the second group meeting as regards how to assess student learning in order to know how students progress or construct their understanding, in

second cycle Benja designed a variety of assessment methods. Questioning was used in different sessions of classroom activity. First, she asked questions in order to asses what students knew about the relationship of each particle in an equilibrium state, and in the meantime to review students' previous knowledge about the chemical equilibrium state. Second, during her explanation of the new concept about the equilibrium constant, she asked questions aimed at helping students to understand clearly what they were studying. Third, she posed questions that required students to summarize what they had learned, for example: 1) What did you learn from the equilibrium constant? 2) At the equilibrium state, how did the equilibrium constant differ between the forward reaction and the reverse reaction?

Exercises were used after her explanation of the main concept. Students were required to participate in learning assessment by playing their role as assessor. Benja distributed the key to each group and had them check their answers against the answer key. Students were allowed to make decisions as to whether or not the answers were right. Prior to checking the answers, Benja informed students how to check their work: "We will check your work together, looking at the key. You check a right mark with the right answer and a cross mark with the wrong answer. Then you have to explain to your peers how you gave the marks to their work." (Classroom observation: Benja, Dec 19th, 2008).

In order to assess individual student's understanding, students were asked to do the test. The tests were written and multiple choice ones. Because of lack of time, the test was a take-home one, and students were allowed to open the textbook when answering it. Classroom observation was another assessment method that Benja used to assess student's behavior in the classroom. While students were working on their tasks, Benja walked around the room and observed closely how students worked cooperatively. Student's journal writing was an approach that emerged in the second cycle to get student's feedback on their learning progress. Students were required to write on four main questions, consisting of: 1) What had you learned for today's class, 2) What problems had occurred during today's class, 3) What did you like in today's class, 4) What did you not like in today's class, 5) What you would like the teacher to

change in her teaching and your learning activity. This journal was adopted from the first meeting, as presented by myself.

In summary, in the second cycle, Benja used various assessment methods and tools to assess how students construct understanding and meaning. She observed when students were involved in activity; used class discussion, and tests after teaching to assess individual student's construction of understanding. In addition, she also began to use student journals as an alternative way of assessment to improve teaching and learning activity. In this second cycle, it was obvious that Benja had changed her practice in assessing student learning by using various assessment methods and continuously assessed students' learning rather than just assigning tests, using questioning, and having students doing exercises in the textbook, as was the case in the previous semester.

In the third cycle, even though Benja attempted to use the same assessment methods as in the second cycle, because of lack of time she emphasized only some assessment methods. In this cycle, she mainly used questioning, exercises, and observation. The exercises contained various questions that required students to demonstrate how to solve problems. Similar to the second cycle, students had the opportunity to correct their work and were a part of assessment process.

During classroom observation, in order to check and correct students' answers, Benja distributed the answer key to each group and allowed students to check their work against the key. She then randomly selected one piece of students' work per group to check by herself in order to convince herself that students' were checking the answers in the right way. Benja described what she found when asking students to participate in learning assessment:

> It was nice. I had them check their answers themselves to see if their answers were right. Then they could talk and ask for reasons for both right and wrong answers by studying the answer key that clearly explained those answers in

detail. Thus they could learn and know what lead to the wrong answer and why. (Interview after teaching: Benja, Jan 30th, 2009)

As mentioned, Benja clearly described how to allow students to check their work, and how students could learn from those activities. However I found that in real classroom situations, she did not clearly inform students as to the role and procedure they had to use in checking their work. Therefore I suggested her to carefully inform students about the proper procedure to check their work; otherwise they would just check and revise their answers directly from the answer key.

In summary, in the end Benja had a pretty good understanding of assessment methods, and she used those methods to cover all learning dimensions. Initially, she only played a role as assessor. In the second and third cycle she changed her practice and developed assessment methods and tools that allowed students to share their ideas on their learning activity. Her practice was considerably changed from the first semester, when she always assessed students only by questioning and sometimes had students doing exercises in the textbook.

Role of the Teacher

The Multiple Roles of the Teacher

It's my understanding that in teaching based on constructivist principles students have to summarize totally what they have learned without any help from the teacher. But I oppose this idea since I think that I as a teacher have to guide them to an understanding of the concept or explain for them. (1st Group meeting: Benja, Nov 8th, 2008)

After talking about the teacher's roles in the first group meeting, Benja learned that guiding or facilitating students was also the teacher's role in the constructivist approach. In her class on the concept of chemical equilibrium, during class observation

Benja posed questions and then guided students to find their own answers. After Benja was finished teaching, she and I talked about her role as follows:

Benja: Sometimes students could not answer some question, and therefore I have to tell them the answer even though I do not supply all the information that I have asked them for. Is this teaching based on the constructivist approach, if I tell them a part of the answer?

I: Certainly, this is one role of the constructivist teacher that you guide your students.

Benja: I have been confused if I try to teach based on the constructivist approach. I have believed that the teacher's role, according to this approach, is to ask students to do their own study; for example, students conduct experiment and make conclusions by themselves.

(Interview after teaching: Benja, Nov 21st, 2008)

In this conversation, I talked about the teacher's role as one that either motivated students to think or gave students an explanation, in the hope that this could help Benja reach a better understanding of the roles of the teacher in the constructivist approach.

In the second group meeting, Benja shared her experience in attempting to be a facilitator, saying: "Even though I have insufficient time to ask all students in one hour, I try to encourage almost all students to answer me so as they can be proud of their own ability." (2nd Group meeting: Benja, Dec 6th, 2008).

As mentioned above, it was obvious how Benja gradually changed her role to be a motivator and facilitator on asking and waiting for all students' responding rather than to be an information provider who less emphasized on asking all students as she performed her practice in previous semester.

In the second cycle, Benja motivated her students' thinking by asking questions until students arrived at an understanding as to what they were going to do. She put more emphasis on students' problems. She always walked around the classroom and observed how students worked. She had interaction with students and gave students suggestions. One example of interaction occurred when, during class observation of the lesson on the equilibrium constant, Benja facilitated a student by using questioning until this student could understand and answer her own question, as below:

Student: I have a problem with the third item.

Benja: With this item you do not need to balance the equation. (Benja went to the student and looked at her sheet.)

Student: Yes, but what I wonder is, if it is the forward reaction it means the products are formed more than the reactants are. Am I right?

Benja: We already have learned about the equilibrium constant, have we not?

Student: Yes, if the equilibrium constant or K constant is of a higher value than one, the mixture will be mostly product. If the K constant is much less than one, the mixture will be mostly reactant.

Benja: As you say, that means that the rate of forward reaction is not equal to the reverse reaction as the equilibrium point. Is this what you mean?

Student: Yes, but actually it is equal.

Benja: So how do you explain the trend of this reaction?

Student: Before reaching the equilibrium point the rate of forward reaction is more than the rate of reverse reaction.

(Classroom observation, Benja, Dec 19th, 2008)

Additionally, as a facilitator and teacher as a researcher Benja developed learning activities to support students' group work. As she mentioned, in the first cycle she had problems with having students doing group work. Therefore in the second cycle she developed the process of group work that allowed students to work in their group cooperatively. In this activity, she clearly informed aims of activity, and

provided handouts which students could study by themselves and work on with their friends.

In the third group meeting, during discussion of the concept of compound solubility which was one topic in Dara's lesson plan, the conversation below revealed how well teachers understood the teacher's roles in the constructivist approach.

Benja: If I teach this concept I will encourage students to discuss experimental results together in analyzing the results. Because of one role of teacher is as a guide. It does not mean we leave students to themselves discuss and analyze without any help from teachers. Therefore we have to ask some questions or provide some suggestions.

Aree: We ask question to encourage them to think. Am I right?

Benja: Yes. For example, regarding your result, I will ask students to conclude by using this question: What about those compounds' solubility?

(3rd Group meeting, Jan 10th, 2009)

In the third cycle, Benja not only designed learning activities which emphasized asking questions to encourage students to participate in a class discussion, using group activity, and creating instructional materials to facilitate students' participation in their learning activity. In her class, Benja walked around the classroom and asked questions to prompt students to think, and at the same time she provided suggestions to those who were faced with some problems: "I saw what students did exercise incorrectly such as they did not balance equation. Therefore I had to tell them what they should do; otherwise they would do it incorrectly." (Interview after teaching: Benja, Jan 30th, 2009) In addition, Benja also used students' opinions to be a part of learning activity: I have found in students' journals that they are afraid to have their mark or score reduced if their answers are wrong. Therefore now I do not punish them by that way." (Interview after teaching: Benja, Jan 30th, 2009)

In summary, Benja gradually developed her role to be a guide, a facilitator, a motivator, and a researcher. In the previous semester, even though she always encouraged students to think by questioning and she sometimes allowed students to carry on short discussions in their group, it was obvious that she played her role as information provider who emphasized teaching based on the textbook and gave insufficient time for students to think about the material. In this second semester, she initially had a limited understanding about the teacher's role as one that allowed students to search for their own results without any assistance from the teacher. After discussing and sharing in the first group meeting, Benja changed her mind and then improved her understanding of the teacher roles based on constructivist approach. Throughout the first cycle to the third cycle, she facilitated students' learning in several ways, through multiple roles of teacher, including: the use of questioning to encourage students in thinking, the use of discussion in their group, the preparation of instructional materials, and help in summarizing the main concept. In addition, she also used what she found from students opinions to develop and improve teaching and learning activities. Benja also was a teacher as a researcher who searched for the better way for student learning.

Common Findings among Three Cases

Common findings were derived from a cross-case analysis of the three in-service chemistry teachers' changes in their teaching practices over the course of the three cycles. The common themes were emerged in the findings of teachers' changes in their approach to teaching as a major dimension of teachers' professional development in collaborative action research. Their changes and the causes for these changes are discussed and presented below.

The Changes in Teachers' Understandings of How to Eliciting Students' Prior Knowledge

The teachers changed their methods of eliciting student contributions, opinions and views before introducing the lessons, and showed more respect for students' ideas.

Teachers had some understanding of the importance of eliciting students' prior knowledge and of attempting to select appropriate methods to elicit their students' prior knowledge. The methods used by the teachers in eliciting their students' prior knowledge involved activities such as asking open ended questions or generating group discussion as pair and group work; these were adapted to suit the particular classes that they were teaching. Even though the three teachers were similar in terms of their approach to eliciting students' prior knowledge, they were slightly different in their teaching practice, which depended on their background knowledge, their skills in applying the new strategy, their ways of knowing, and their working conditions in which teachers were granted enough time to change (Ottoson, 1997; Meyer, 2004; Smith and Gillespie, 2007). For example, Dara still struggled with eliciting students' prior knowledge since she did not hold an adequate conception of prior knowledge.

There were several significant activities to make the teachers become aware of the role of prior knowledge in learning, and how to use students' prior knowledge in learning activity. In this study it involved alerting teachers to their own understanding of students' prior knowledge, confronting them with alternative conceptions, and engaging them in exploratory activities to construct new understandings and conceptions. Most importantly, it was developmental in the sense that teachers primarily determined their initial perception of prior knowledge, and they then actively engaged in learning, practicing and sharing how they could use students' prior knowledge to facilitate students learning. The teachers demonstrated that changes did not have to emerge from an outside agency, as for example being given information by facilitator 2 or me; rather, teachers already possessed what they needed to improve their teaching. It was linked in their own minds between which was known about prior knowledge and which they were coming to know by actively participating in their own learning.

The factors that affected the use of what was learned in this study were help from colleagues (Ottoson, 1997). Teachers had opportunities to construct and reconstruct their knowledge by sharing their lesson plans, and reflecting on their teaching experiences as well as learning from the explanations of both their peers and

facilitator 2 and I about assessing prior knowledge in the group meetings and linking what they had learned to a real classroom setting. The teachers were engaged in a continuous process of improvement, which provided support for teachers to think through the inevitable dissonance experienced (Loucks-Horsley *et al.*, 2003). In addition, discussions with me after teaching motivated the teachers to be aware of the appropriateness of certain methods to assess students' prior knowledge. The changes also related to the teacher's confidence in explaining to me, in an open and friendly atmosphere, how they developed questions in eliciting students' prior knowledge.

In summary, the teachers developed their practices to become aware of students' prior knowledge and developed assessment methods aimed to elicit students' prior knowledge. They were concerned about students' incomplete understanding, and helped those students to shape their understanding before learning new concepts, and then they linked students' prior knowledge to the new concepts (Vadeboncoeur, 1997; Baviskar *et al*., 2009). The factors determining how teachers changed can be divided into two agencies: the insider agency comprising the teachers themselves, and the outsider agency consisting of their colleagues and the researcher team.

The Changes in Teaching Strategies

The second change was in which teachers changed their teaching strategies. They now used a mix of methods and strategies when teaching. They had shifted from a lecture-based approach to a constructivist-based teaching approach, which allowed their students take more responsibility for their own learning. Their teaching demonstrated an emphasis on strategies, processes, and thinking with task-based or activity-based lessons. As for materials and resources, there was more consideration of a change in the availability of a much greater range of resources for teaching, instead of relying on the prescribed textbooks and covering everything in them. Aree for example added the use of measuring instruments to her lesson. Rather than just having students conduct the experiment based on the prescribed textbook, the teachers created materials chosen for their relevance to students' current activities.

Students were engaged in the process of constructing their own understanding of the concept being taught through hands-on activities and the encouragement of critical thinking. For example, the teachers posed questions, and allowed students to set a hypothesis to answer the questions, to discuss the experimental procedure, to conduct an experiment based on the procedure discussed, and to make their own conclusion and present it to the class.

Their changes were occurred over time in which it was not immediate or complete, with the collaborator or colleagues serving only to initiate the process (Freeman, 1989). Their approaches to implementing these teaching activities had similarities and differences based on several factors. For example, Benja focused primarily on having students discuss the experiment based on her oral questioning, rather than allowing students to carry on a discussion in their own group as to what they were studying and how they should go about doing the experiment. She strongly believed that discussion after conducting the experiment was the most important method, in that students could only gain the correct concept from a class discussion and conclusion. Her practice demonstrated that she did not emphasize purely intellectual activity but students' hands-on activities and a correct explanation. It has become an accepted idea that teachers' beliefs play an important role in their judgments and in shaping teachers' characteristic patterns of instructional behavior in the classroom (Pajares, 1992; Thompson, 1992). Besides, experience also is a necessary component of expertise (Rich and Almozlino, 1999). For example, in Dara's classroom, even though over the course of the project students were given more opportunity to participate in conducting the experiment, and more students were encouraged to participate in conducting the experiments during class demonstrations, nevertheless she still tightly controlled the learning activities and was concerned to cover all information, as most of her experience lay with lecturing and she had far less experience of the constructivist approach. Joughing (1992) proposed that some teachers have an analytic ability to understand a strategy and how to use it whereas other teachers need more structure to grasp and then apply a new strategy. The other factors affecting teachers' changes were such enabling factors as available resources, opportunities to apply what has been learned, and sufficient time for preparation (Ottoson, 1997).

However, there were several reinforcing activities which were significant to make the teachers change their teaching strategies. In line with the autonomy and the responsibility of all teachers as adult learners, this project was to provide a climate that gave teachers the sense that they were in control of their own practices and that supported them as they took systematic action to improve their circumstances (Loucks-Horsley *et al*., 2003; Collin, 2004; Stringer, 2007). In addition, this study emphasized recurring cycles of planning, acting, observing, reflecting and examining their practices, and then modified the plan and allowed them to use their own understanding to inform both practice and their inquiry (Oja and Smulyan, 1989; Loucks-Horsley *et al*., 2003). The teachers did not proceed in isolation, but rather were provided with opportunities to collaborate with colleagues and facilitators to improve their practices (Loucks-Horsley *et al*., 2003). Collaboration provided teachers with many different perspectives, and supplied them with the time and support necessary to make basic changes in their classroom practice and their approach to professional problems (Elliott, 1977). Discussion after teaching with me as the facilitator motivated the teachers to be aware of the appropriateness of learning outcomes, teaching strategies, and instructional material for a specific content, with the goal of improving practices (Oja and Smulyan, 1989).

In summary, the teachers developed their practices by creating more opportunities for students to engage in learning activities through both hands-on and mind-on activities, rather than simply the teachers giving students the information, as was the case in their teaching practices in the previous semester. Even though the changes the teachers underwent were not complete as regards teacher belief, teacher experience, their way of knowing, and school condition, they were able to change their practices to conform closer to the constructivist approach. The impact of the action research group, collaboration with other teachers and researchers as facilitators, and reflection in recurring cycles were all significant in engineering changes in the teachers' teaching strategies.

The Changes in the Teachers' Practices regarding the Role of Social Interaction

All three teachers used a variety of teaching techniques to incorporate cooperative learning into their classroom methods. Worksheets and handouts were typically used extensively in this approach. The teachers become more aware of cooperative learning rather than asking students to simply work or teach each other. The teachers arranged learning activities that assigned students into small heterogeneous groups working together to achieve a common goal of each lesson. They tried to inform students clearly about the aims of cooperative learning activities, the procedure of cooperative learning, students' roles, and how to assess their cooperative group work. The teachers conducted fewer lectures and instead made more time for a variety of group activities. Teachers used group work such as writing assignments and games to promote cooperative learning in their lessons. The activities in their classes were aimed at moving closer to the basic elements of cooperative learning: positive interdependence, individual accountability, equal participation, simultaneous interaction, face-to-face interaction, use of small-group skills, and regular group processing of current functioning to improve the group's future effectiveness (Johnson and Johnson, 1987; Johnson *et al*., 1991). However, the teacher's skill in applying the cooperative learning methods, their analytic ability to grasp new understanding, their opportunity to apply what they had been learned, and the students skills to work in group affected the success of their integration of cooperative learning into their classroom procedure (Ottoson, 1997; Zakaria and Iksan, 2007). For example, even though Dara tried to apply many approaches in her class, students were often not willing to perform in accordance with her suggestions since they were used to being purely passive learners.

Even though their instructional changes were not complete, they did demonstrate that major changes had occurred over time. Significance in helping the teachers understand the feature of cooperative learning was the instruction from both I as a facilitator and the other members of collaborative action research group about cooperative learning activity. The activities in our group meetings were conducted in a learning atmosphere and aimed to support all members through cooperative learning as

a way to learn together to reach the common goal in teaching based on the constructivist approach. Regarding constructivist theory, the teacher as learner was viewed as an active agent of learning that could learn through social interaction. From this interaction, the teachers constructed their own meanings (Vygostky, 1978). Collaboration was one of the key tenets of action research which allowed for mutual understanding, democratic decision making, and common practice (Carr and Kemmis, 1986; Oja and Smulyan, 1989). In the learning atmosphere of this study, a experience teacher in cooperative learning such as Benja who benefited from having to formulate her thoughts and knowledge into concepts understandable to others, while an less experienced teacher in cooperative learning such as Dara benefited from the explanations of their peers, and was thereby helped to restructure and deepen her understanding. Besides group meetings, teachers undertook teaching with the new approach and reflected on their practices that could help them to learn more about integrating cooperative learning into their classroom.

In summary, the teachers changed their practices by creating more opportunities for students to engage in learning activities through cooperative learning rather than simply sitting in group and work individually such as had characterized their teaching practices in the previous semester. Even though the changes of teachers were not complete depending on teacher experience, ways of knowing, the nature of students, and school conditions, the teachers were nevertheless able to incorporate significant aspects of cooperative learning into their classroom procedure. Experience with the action research group, collaboration with other teachers and researchers as facilitators, and discussion after teaching with me, were significant factors in changing the teachers' teaching strategies in each cycle of this study.

The Changes in Teachers' Strategies to Assess Students' Learning

All three teachers used two types of assessment to assess students' learning: formative and summative. Formative assessment occurred during learning activities. It included class discussion, questioning, observation, exercises and reports. Summative assessment occurred in the form of midterm and final examinations. Even though the

teachers still used exams and tests to assess students' achievements based on school policy, they also developed other assessment strategies which balanced formative and summative assessment. They tried using more continuous assessment, attempted to predict students' difficulties, and used assessments as a basis for improving teaching and helping students (Loucks-Horsley *et al*., 2003). The methods were mostly simple, non-graded, and included in-class activities that gave both the teachers and their students' useful feedback on their teaching and learning activities. The teachers used assessment each day as short-term feedback about the learning and teaching process, and then they used that information to plan better learning activities and restructure their teaching. Furthermore, students were asked to be involved in the assessment process, which provided the teachers with information on the effectiveness of the learning activities that they had designed for use in their classrooms.

Analyzing their lesson plans together during group meetings and discussions, and talking about their teaching with me were significant activities that helped the teachers become aware of the need to use formative assessment for determining how students learned. Collaborative action research demanded that teachers plan, act, observe, and reflect on their practice so as to improve their understanding, and that practice took place in the context of a classroom setting (Collins, 2004). Teachers had the opportunity to develop immediate and deeply relevant understandings of their situation after receiving feedback, and this led them to be involved actively in the process of dealing with those problems (Stringer, 2007).

In summary, all teachers changed their practices due to strategies to assess students' learning by using a variety of assessment methods and tools that emphasized various dimensions, rather than merely the cognitive dimension as was the case in their practice of the previous semester. Participation in the teachers' group, discussions with me, and active involvement in their classroom practice were the main influences leading to these changes.

The Changes in Teachers' Roles

There was change in the role of the teacher to be a guide, a facilitator, a motivator, and a resource person for learning. The teachers became aware that an important part of organizing the learning activity and creating an environment to support student understanding could be achieved by changing their role to play a multiple roles rather than simply a transmitter of information. They coached, prompted, and helped students to develop and to assess their understanding, and thereby their learning. The teachers adapted their role from that of an information provider where the teachers gave a didactic lecture that dutifully covered the subject matter, to that of a facilitator where the teachers helped the students to achieve his or her own understanding of the content. With a multiple roles, they asked more open ended questions, provided guidelines, created the environment for the students to arrive at his or her conclusion, helped the students in describing what they were experiencing without demanding one particular explanation, designed ways for students to do both hands-on and mind-on activities, provided resources, encouraged students to participate in classroom discussion, and gave students' an opportunity to revise their work in order to improve their learning results (Rhodes and Bellamy, 1999; Windschitl, 2002; Vighnarajah, Luan, and Bakar, 2008). They tried shifting students from a passive role to an active role in their teaching and learning activities.

The teachers benefited from the accumulated understanding that was the result of reflection on past practice and experience during the interactions and discussion in the action research group meetings. Facilitator 2 and I attempted to model these roles by acting during group meetings. In the contexts of their classrooms, the teachers asked questions and gathered information that continued to shape their practices, and then they applied what they discovered to subsequent classroom teaching and learning activities. The teachers took a special interest in helping a student optimize a learning experience and assisted the student's socialization through cooperative learning.

In summary, the teacher's role in the classroom changed from the previous semester to one which sought to facilitate students' efforts to construct their own

understanding. Analyzing lesson plans together and the use of role playing by facilitator 2 were significant activities that made the teachers change their roles to facilitate student learning.

Summary

The teaching practices of these chemistry teachers revealed that over the course of the collaborative action research group meetings they were able to develop their practice in ways that were much more closely aligned to constructivist teaching methods. As described and documented above, these practices included: (a) changes in teachers' understandings as to the best way to eliciting students' prior knowledge, (b) changes in teaching strategies, (c) changes in the teachers' practices regarding the role of social interactions, (d) changes in teachers' strategies to assess students' learning, (e) changes in teachers' roles of facilitating students' learning. Chapter 6 will be devoted to the conclusions of the research finding of this study, implications of the study and suggestion for further research.

CHAPTER VI

CONCLUSION AND IMPLICATIONS

Overview of the Chapter

This chapter describes the conclusions of the findings, their implications to the science education research community, and suggestions for further study. First, the review of the research framework for the study is described. Second, the conclusions for each phase of the study are described, including the chemistry teachers' teaching practices in the first phase of the study and the understanding of the changes of teachers' teaching practice as a result of participation in the CAR group. Third, implications of the study are described. At the end of this chapter, some suggestions for future research are presented.

Review of the Research Framework

Science education in Thailand is part of the educational reform which is aligned with the National Education Act 1999. According to this reform, Thai students are intended to learn science as part of lifelong learning, with a balance of knowledge, skills and attitudes, in order to achieve scientific literacy. With all these changes prescribed in the Act and geared towards the reform of teachers and the teaching profession, it is necessary to give careful consideration to teachers, the process of change in their teaching practice, and other related issues. However, there have been some obstacles that have hindered the success of Thai science education. One is the teachers' lack of understanding of constructivist-based or learner-centered teaching approaches and their lack of techniques for facilitating the development of higher-order thinking skills, and for using new technologies in their classrooms (OEC, 2005; Dahsah, and Faikhamta, 2008). For teachers to develop the competencies necessary to implement teaching based on the constructivist approach, they need a clear understanding of the disciplinary knowledge in the new curriculum, new learning strategies, and new assessment and evaluation methods. However, most professional

development programs for educators were short-term workshops, and after participating in the workshops there was no support from central education agencies, with the result that the participating teachers did not have the confidence to implement changes.

In essence, initiatives must be undertaken to further on-going professional development work in order for teachers, administrators, and facilitators to improve their understanding and skills (Atagi, 2002; Fry, 2002; Pillay, 2002). One recommendation on learning reform was to promote collaborative action research and encourage teacher education institutions to work together with the schools. Therefore, this study was conducted to examine the change in chemistry teachers' teaching practices based on exposure to the constructivist approach through collaborative action research.

There were two phases of the study. In first phase, research was conducted to provide insights as to how the teachers performed their teaching practices in Chemistry instruction, and which focused on lesson introduction, teaching and learning activity, social interaction in classroom, learning assessment, and teacher roles. The participants of this study were three in-service chemistry teachers teaching at different secondary public schools under the Bangkok Educational Service Area, Office 2. In order to understand the performance of in-service chemistry teachers, multiple data sources have been used during the research process. These were: classroom observation, semi-structured interviews, and teachers' lesson plans.

The second phase, the research conducted to understand how the teachers changed their practice and applied their new understandings about constructivist principles in their classroom during participation in this study. The CAR group, including three teachers, one science educator and myself, was developed to work together. Throughout the process in the second phase, there were three cycles of the collaborative action research. The activities in each cycle consisted of one group meeting held at Kasetsart University, which occupied approximately 3 hours. After the group meeting I had one-to-one individual teacher meetings in helping the teachers to design lesson plans which could be implemented within their own classroom setting.

The cycle of action research began with a CAR group meeting in which the members shared their experiences about teaching based on constructivist principles, discussed problems of teaching , suggested way to solve problems, and helped each other to designed lesson plans in collaborative circumstances. After the group meeting the teachers adopted what they learned to redesign their lesson with the assistance of myself, and then the teachers implemented their lesson plan in their classroom. Having finished teaching each lesson, they reflected on their teaching. The new cycle occurred when the teachers contributed their experiences to the CAR group meeting and group members learned from each other when they reflected on what had happened in the classroom and revised the next lesson plan accordingly. The data collection came from multiple data sources: participation in group meetings, classroom observation, semi-structured interviews and teachers' lessons. The approach to analysis used here involved an inductive process: a search for correspondences and patterns and make themes of common findings. Within-case analysis was made prior to cross-case analysis. The overview of research framework is shown in figure 4.

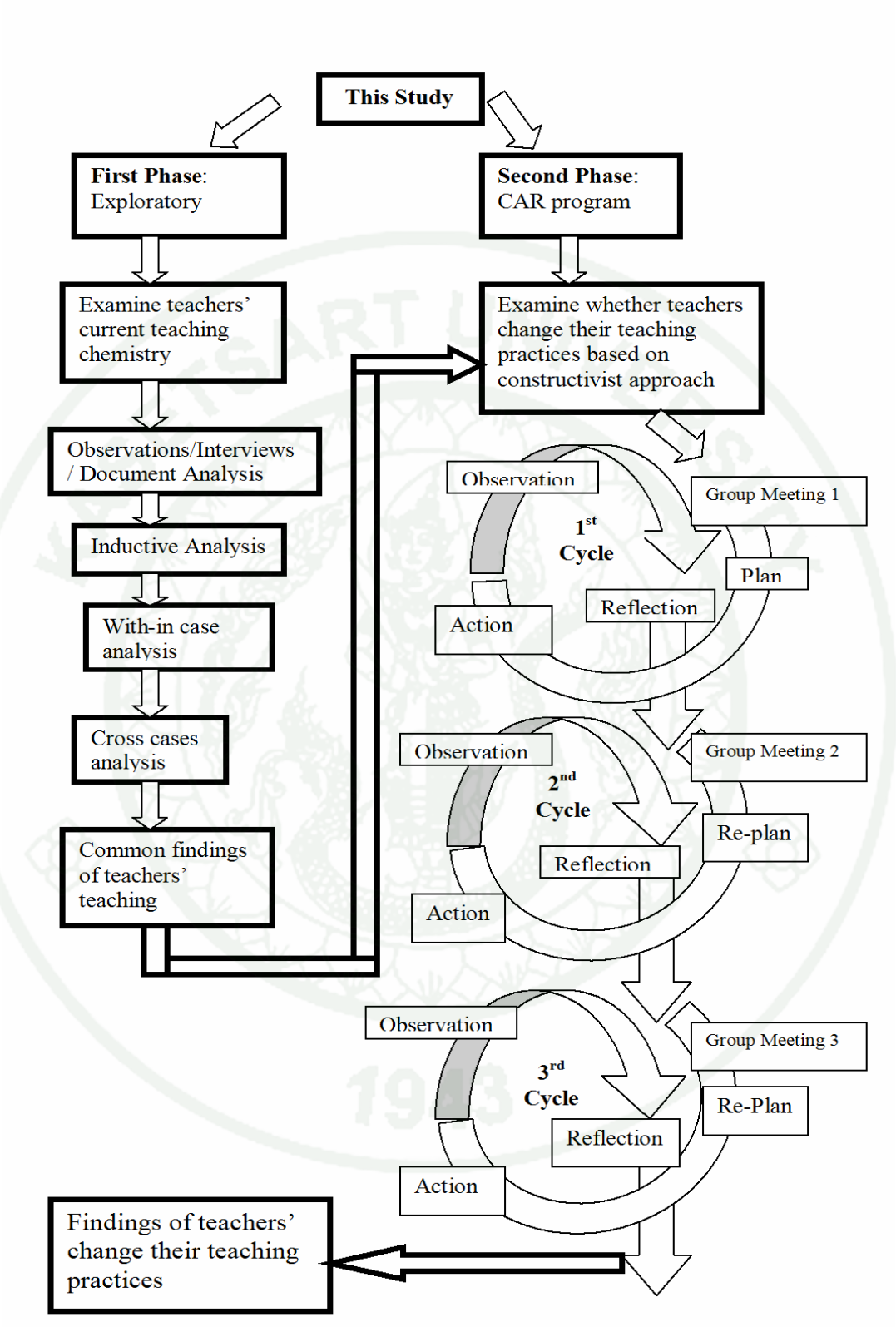

Figure 4 Research Framework

Conclusions of the Study

First Phase: Teachers' Teaching Practices before Participation in the CAR

For the first phase of the study, the findings indicated that the teachers did not teach chemistry in line with the National Science Curriculum Standards and the National Education Act. The teachers were not aware of students' prior knowledge, either of individual students or the whole class, and so this was ignored before teaching a new concept. The teachers were more concerned about conveying and covering the content knowledge. All three chemistry teachers carried out the fundamental purposes of organized learning activities similarly in terms of conveying information to students and helping them achieve conceptual understanding. The teachers demonstrated that their practices were still adhering to traditional teaching, in that teachers had authority over student's learning and emphasized teaching based on the textbook. They further emphasized teaching through lectures and demonstrations to transmit content at a faster pace, stressed the need to do assignments, rarely encouraged students to use scientific methods to solve problems, and conducted experiments but based narrowly on the procedure mentioned in textbook. They had students do group work without clearly informing them about the process of cooperative group work. Therefore some students still worked individually. And their approaches in using group work did not encourage all aspects of cooperative learning into their classrooms; teachers allowed students to work in groups to reinforce concepts taught by teachers, but it was simply students teaching students and simply group learning activities. All three chemistry teachers used several methods of learning assessment to evaluate students' learning. However, they still conducted themselves in accordance with traditional assessing methods which narrowly emphasized right answers being given, tests separated from learning, and on the cognitive dimension of students' learning outcomes. They used as the main method a work sheet that clearly delineated the right answer. In addition, asking questions was often used as the means to get the only right answers from the students. And they emphasized tests which were separated from teaching and learning. The three teachers did not emphasize the assessment of the other dimensions of learning outcome such as skills or attitudes. The teachers played their various teaching roles with much the same

fundamental purpose aiming to improve student achievement. However, they continued teaching using traditional methods in which teachers were mainly information providers, individual planners and assessors. They made decisions as to what and the how of the learning process, for which they overly relied on the textbook. As regards learning assessment, all three chemistry teachers acted as individual assessors to evaluate student learning without asking students to participate in their learning assessment.

Second Phase: The Changes of Teaching Practices As a Result of the CAR

The Changes of Teaching Practices

As a result of the study, the teachers gradually changed their practices to be aware of eliciting student prior knowledge before introducing the lessons, and showed more respect for students' ideas. Teachers gained some understanding of the importance of eliciting students' prior knowledge and of attempting to select appropriate methods to elicit their students' prior knowledge. They changed their teaching strategies by using a mix of methods and strategies when teaching. They had shifted from a lecture-based approach to a constructivist-based teaching approach, which allowed their students to take more responsibility for their own learning through hands-on and minds-on activities.

As for materials and resources, there was more consideration of a change in the availability of a much greater range of resources for teaching, instead of relying on the textbooks. All three teachers attempted to use a variety of teaching techniques to incorporate cooperative learning into their classroom methods. Worksheets and handouts were typically used extensively in this approach. The teachers become more aware of cooperative learning, rather than asking students to simply work with or teach each other.

All three teachers developed assessment strategies which balanced formative and summative assessment. They tried using more continuous assessment, attempted to

predict students' difficulties, and used assessments as a basis for improving teaching and helping students. Furthermore, students were asked to be involved in the assessment process, which provided the teachers with information on the effectiveness of the learning activities that they had designed for use in their classrooms.

There was change in the role of the teacher from information provider to that of a guide, a facilitator, a motivator, and a researcher of students' learning. The teachers became aware that an important part of organizing the learning activity and creating an environment to support student understanding could be achieved by changing their roles. With multiple roles, they helped the students to describe what they were experiencing without demanding one particular explanation, designed ways for students to do both hands-on and mind-on activities, provided resources, encouraged students to participate in classroom discussion, and gave students an opportunity to revise their work in order to improve their learning results.

However, the teachers' practices did not change overnight. The rate of change varied in accordance with the teachers' experience, their background knowledge, their analytic ability to grasp new concepts and ideas, whether or not their working conditions granted the teachers enough time to change, and finally the students' skills. This study illustrates the small steps the teacher as researcher took individually and collectively to enact a new approach for chemistry teaching and learning based on constructivism.

The Teachers' Professional Growth through CAR

The CAR group demonstrated that chemistry teaching could be radically improved via the direct action of teachers who took risks, asked themselves questions, and recognized the value of collaborating in our group, a collaboration that was reported as having significant professional and personal benefits. In line with the autonomy and the responsibility of all teachers as adult learners, they were in control of their own practices when they took systematic action in each action research cycles. The teachers could make decisions to plan the creative process of teaching, could

change their practice, and reflect on and evaluate their practice so as to improve students' learning in their classrooms.

Collaboration with other CAR members also was significant in engineering changes in the teachers' teaching strategies. As a collective group, the teachers shared pedagogical techniques, presented results from their own experience, and posed new questions about limitations relative to their attempts at teaching based on constructivist principles in their classroom. The teachers were engaged in a continuous process of improvement and collaboration with other CAR members were significant factor in assisting teachers to construct their own deeper understanding and ultimately to change their teaching strategies in each cycle of this study.

Implications of the Study

Implications to Improve Teaching and Learning Chemistry

In chemistry education many issues such as low student performance and negative attitudes have often been mentioned. One principle problem is that chemistry teaching remains overly dependent on textbooks which contain too much content. Teachers need to restructure their teaching in a way that helps students understand important ideas that foster scientific literacy, which requires a shift from teacher-dominated classrooms toward more constructivist , student-centered learning.

Teaching based on constructivist approach was not an ideal or teaching theory to be achieved but rather a process to be developed while teachers learned about constructivist principles and experienced a constructivist learning environment. It was developmental in the sense that teachers primarily determined their prior perception of constructivist teaching principles, actively engaged in the teaching and learning process rather than attempting to receive knowledge passively, re-examined their own experiences in chemistry teaching; re-thought how they wanted to make chemistry more meaningful and understandable to their students' diverse capabilities and interests, and re-constructed the power structures within which teachers did their work.

Furthermore, teachers needed to engage in productive and reflexive conversations and become collaborators who support a discourse for new understandings for constructivist teaching in their classroom. Only then can teachers create their own knowledge, critique that of others, and evaluate their own growth.

Through participation in CAR, the teachers showed that their understanding was built around principles of constructivist theory in those teachers themselves were learners. The teachers could learn through hands-on and minds-on activities when they conducted their own research. They could develop their understanding through cooperative learning when learning with CAR group member. In this study, the teachers illustrated how constructivist principles could be integrated in a manner that reflects the aims of the Act (ONEC, 2003) and at the same time supports chemistry teaching. The students also benefited from the understanding that each teacher gleaned from their own action research. The teachers developed a more holistic understanding of the value of questioning and data gathering, and they, in turn, used this knowledge to enrich their classroom lessons.

The finding of this study can be used for the professional development of other groups of chemistry teachers. The professional development program should provide opportunities for teachers to experience or learn about constructivist principles by their own action research and become a part of the way that teachers think about and plan for their teaching and learning process.

Implications for In-Service Science Teacher Professional Development

Collaborative action research in this study refers to the collaboration by teachers with researchers as facilitators who encourage and support teachers. The model for CAR involved teacher collaboration and reflection with CAR group members to address problematic issues in their classrooms and schools and to construct a new understanding of teaching and learning based on constructivist principles. The teachers' knowledge and understanding can grow through real situations and through practice in action research. Then, action research can be embedded in teachers' practice, and can

play an important role in teacher education and the reform of science education. Based on the results of this study, it is suggested that professional development should provide an opportunity for teachers to practice in their own context. The crucial issue is how to encourage teachers from CAR group members to be mentors and facilitators for their colleagues and carry on their own school-based research in order to form communities of learners to collaboratively support and stimulate personal and professional development at the school-level. In order to convince other science teachers that they can create new teaching methods, the teachers from CAR group need to demonstrate how they are contributing to new practices and thereby persuade other teachers that they also can initiate a new teaching practice. The another important thing is the need to influence school principals to see the benefits of these new ways of working, so that they will put in place the basic means to enable other science teachers to continue creating their new teaching practices. In this change, the principals need to rethink the power structures in which teachers do their work. The implication of this study is that the collaboration between the principals with this group of chemistry teachers or other science teachers to take action toward changing science teaching. This may consist of devising ways teachers can work effectively with principals to implement changes in the repositioning of curriculum, and the scheduling, and resetting of school goals. Collaborative action research projects can be designed as a specific form of teacher development in the context of the implementation of current practice. The purpose of collaborative action research can be to focus on problems and changes in a single classroom, or on several classrooms within a school or across schools.

Suggestions for Further Study

To Change Teaching Practices through CAR, One Has to Take Risks.

An important feature of professional development activities, such as the action research model in this study, is that teachers have to take risks. There were various risks that teachers had to overcome as a way to begin their action research including the challenging in asking and reflecting their own teaching, the force of culture of autonomy and isolation in teaching, the challenges of time to work on action research,

the challenges of a result of action research affecting on the stakeholders, and the challenge on working with other teachers. Teachers need time to explore alternative pedagogical practices, prepare their instructional materials, and develop a strong network with other teachers as a way either reflect on their teaching and listening other opinions on their practices. On the other hand, teachers still need the freedom to enact decisions they perceive of greatest relevance to themselves and their own students as they used to do when doing isolation in teaching. For this reason, teachers must be inspired to join and participate in professional development activities via teachers' own internal motivation. Teachers should be encouraged to take risks as they become active and productive agents of change. Therefore before conducting this type of research, the researcher has to consider all the teachers' risks before developing the professional development program.

To Teach Chemistry Based on the Constructivist Approach, One Has To Be Supported.

The findings in this study show that teachers are enthusiastic about making a difference for their students in their new teaching approach. However, the teachers also confronted difficulty in adopting and adapting constructivist principles into their classroom practice. Consideration must be given to the language and literature used in presenting and describing constructivist principles so that it is more flexible and understandable for teachers to identify and enact. Informal teacher support groups should be created where teachers can examine progressive forms of their teaching and discuss their pedagogical applications and implications of constructivist approach.

Chemistry teachers who participated in this study each constructed individual ideas of teaching based on constructivist approach which were responsive to their own interests, educational backgrounds, students' needs and skills, school contexts and their working conditions, and demands imposed by their respective school communities. Even though teachers needed to create their own idea of teaching based on constructivist approach in their classroom context, in real situations when they participated in CAR, there were no clear cut solutions or common methods to

integrating constructivist principles into their practices. Those educators responsible for developing professional development programs should give attention to the diversity of the challenges that teachers encounter and the ways they choose to overcome them. Teachers' diverse perspectives and experiences should be considered and positioned as one main issue in supporting and facilitating collaboration.

Professional Development should be Emphasized Diverse Groups of Science Teachers.

Since this study only covered a small group of teachers who had long term experience in teaching and had high level of educational background, further studies should follow involve other groups of science teachers teaching' practices through CAR. The suggestion for future research should be focused on the diversity of science teachers including pre-service teachers and in-service teachers who had graduated with different degrees and have a range of teaching. A number of questions arise and need to be investigated: 1) Do the new in-service science teachers change their teaching' practices based on constructivist approach when participation in a CAR program? 2) What is the influence of a CAR program in changing the new in-service science teachers teaching' practices? 3) How does the CAR program promote teaching practice for pre-service teachers? 4) Is there any effect on the different of the teacher educational background on changing their practices? 5) How does the CAR program promote teaching practice for a diverse group of teachers?

In this study the process of the CAR program used three cycles. As the result, it found that the rate of teacher change was different. Further studies should explore the relationship between the number of cycles and length of program on teacher change. Finally, future research should be done to investigate the effect of CAR on the growth of students' learning in parallel to teachers change their practices. Because this study gives attention primarily to professional development, it does not emphasize on students learning. Therefore the growth of students' learning before, during and after teachers' participation in CAR should be studied.

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APPENDIX

Interview Protocol

Interview protocol for data collection in Phase I

1. What are the teaching methods employed in teaching and learning activities?
2. What are the reasons in employing those teaching methods?
3. What evidence is there of students' learning as a result of the teaching methods employed?
4. How does the teacher assess students' learning?
5. What are the strengths and weaknesses of such teaching?
6. What should the teachers do to improve their teaching?
7. Other suggestions

Interview protocol for data collection in Phase II

Interview before teaching

1. What concept will the teacher be teaching?
2. What are the objectives/goals for teaching this concept?
3. What technique or questions are used for eliciting student's prior knowledge?
4. What activities are designed to engage students in learning activities?
5. What activities are designed to support cooperative learning?
6. What assessment methods and tools will the teacher employ to assess student's learning?
7. What instructional materials are used for teaching this concept? How will the teacher support students in the construction of their understanding?

Interview after teaching

1. What assessment methods and tools will the teacher employ to assess student's learning in the real classroom context?
2. How well does the student understand as a result of this teaching?
3. What are the benefits of teaching based on the constructivist approach to learning?
4. How does the teacher change his or her practice or develop an understanding according to constructivist principles?
5. What problems emerged when the teacher implemented the lesson plans?
6. How did the teacher solve these problems?
7. What will the teacher do for the next lesson?

BIOGRAPHICAL DATA

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