THESIS APPROVAL

GRADUATE SCHOOL, KASETSART UNIVERSITY

Doctor of Philosophy (Science Education)

DEGREE

Science Education | Education

FIELD | **DEPARTMENT**

TITLE: Enhancement of Inquiry-Based Instruction of Thai Secondary Science Teachers Using Collaborative Action Research

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THESIS

ENHANCEMENT OF INQUIRY-BASED INSTRUCTION OF THAI SECONDARY SCIENCE TEACHERS USING COLLABORATIVE ACTION RESEARCH

JEERAWAN KETSING

A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
Doctor of Philosophy (Science Education)
Graduate School, Kasetsart University
2010

Jeerawan Ketsing 2010: Enhancement of Inquiry-Based Instruction of Thai Secondary Science Teachers Using Collaborative Action Research. Doctor of Philosophy (Science Education), Major Field: Science Education, Department of Education. Thesis Advisor: Professor Vantipa Roadrangka, Ph.D., Ed.D. 281 pages.

This interpretive case study aimed to examine the changes of three science teachers' understandings and practices of inquiry-based instruction (IBI) as a result of their participations in the professional development program, entitled the collaborative action research program (CAR Program).

The study and the CAR Program were composed of four phases: Preparation, CAR Cycle I, CAR Cycle II, and CAR Cycle III. In the Preparation phase, the teachers' initial understandings and existing practices with regard to IBI were investigated. The findings from this phase were used for comparing and contrasting with the results of individual teacher's understandings and practices in the following three phases. During each phase, the teachers were involved in a similar set of activities consisting of designing, implementing, observing, and reflecting on their own inquiry-based lessons. The teachers then presented their lesson plans and teaching experiences for discussion with the other participating teachers in a series of group meetings that were part of the CAR Program. The findings of this study were obtained from multiple data sources including individual interviews, teachers' lesson plans, teachers' written reflections, classroom observations and group meetings. The data were analyzed by using a within-case analysis and followed by a cross-case analysis.

The results demonstrated an improvement of teachers' understandings and practices of IBI after attending the professional development program. In addition, the teachers' understandings and practices shifted from focusing on teacher-directed inquiry to learner-directed inquiry. All three teachers fully understood and practiced student-directed inquiry in terms of the role of a teacher, the role of students, and the instructional objective. For the instructional process, these three teachers conceived and incorporated most of the key features of IBI into their practices. As a result, the professional development program established in this study was seen to be effective in promoting three teacher's understandings and practices of IBI.

The results of this study indicate that the incorporation of the basic elements of collaborative action research within a professional development program is useful for promoting the teachers' understandings and practices of IBI in classroom settings. The present study did not investigate the process the teachers come to understand and change their practice, therefore, further research is needed to understand more fully how science teachers learn to adapt and whether they sustain their new understandings and practices of IBI in the context of professional development activity.

Student's signature	Thesis Advisor's signature	/ /

ACKNOWLEDGEMENTS

This dissertation could have been my long academic journey. The completion of this academic journey would not have been possible without the support, encouragement and guidance of many individuals. First, I would like to express my deepest gratitude to my thesis advisor, Prof. Dr. Vantipa Roadrangka, for her confidence on my ability to overcome all the obstacles, her continuous encouragement, her quick and constant supports, and her patience throughout the process of conducting this research and writing this thesis. I would also like to thank her very much for inspiring me to go on this journey which provided many good opportunities to my life.

I would like to express my sincere thanks to my thesis co-advisors namely Assoc. Prof. Dr. Boongeua Vajarasathira, Prof. Dr. Gaalen Erickson and Assoc, and Prof. Dr. Jolie Mayer-Smith. They were my great mentors who took care, understood, and encouraged me throughout this endeavor. Their guidance in both personally and academically was my best companion along the way.

I also would like to express special thank to my English editor, Assist. Prof. Dr. Niwat Taepavarapruk and Mr. Brett Allison for all of their technical and emotional supports for editing this thesis. I would like to give my special thanks to the three science teachers for sharing their professional experiences and their thoughts in the classroom. Unforgettably, I would like to express my gratitude to the Institute for the Promotion of Teaching Science and Technology for the financial support throughout my Ph.D. study. I would also like to express my appreciation to the Graduate School, Kasetsart University for the research and conference funding.

Last, but not least, I would like to dedicate this work to my grandfather and grandmother who loved me and always gave the warm support at all time until their last minutes. Without them, I would not have grown to be what I am right now.

Jeerawan Ketsing
April, 2010

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CHAPTER I

INTRODUCTION

This chapter provides background information of the Thai educational context, statement of the problems, aims of the study, research questions, summary of research methodology, definition of terms important to the study, and limitation of the study. The chapter is completed by the organization of this thesis.

Background of the Study

During the period of this study (academic year 2008), the education in Thailand has been reformed for almost ten years. The enactment of the National Education Act in 1999 is a remark of a starting point for the education reform. The National Education Act aims to foster the well balanced development of the Thai people (Office of the National Education Commission [ONEC], 2003). According to the Act, compulsory education is extended from 6^{th} grade to 9^{th} grade whilst basic education is expanded from 9^{th} grade to 12^{th} grade. The act decentralizes the administrative systems, reconstructs curricula by emphasizing science and technology, as well as individual learning. As stated in the Act, education management shall be based on the principle that all learners are capable of learning and self-development, and are regarded as being most important (ONEC, 2003). In addition, the Act empowers basic education institutes to design their own curricula which are related to the needs of the community and society, local wisdom, and attributes of desirable members of the family, community, society, and nation. However, the institutes shall follow core curricula for basic education. Consequently, the Department of Curriculum and Instructional Development [DCID] and the Institutes for the Promotion of Teaching Science and Technology [IPST] has responded to the government policy by launching a science core curriculum, so-called “the National Science Curriculum Standards [NSCS]”, in order to set standard criteria for teaching and learning the science subject (DCID, 2002; IPST, 2002).

According to the NSCS (DCID, 2002), science teaching and learning should emphasize the learner as the person who learns and discovers scientific knowledge by him/herself. Students are expected to understand “science” not only scientific knowledge but also the process for acquiring the knowledge. Students are intended to develop science process skills, scientific attitudes as well as positive attitude toward science. To reach these expectations, the NSCS suggests that science teachers should change their roles from the lecturers or transmitters to the planners and facilitators who support and facilitate student’s leanings by designing the learning activities, posing the questions, giving the advices, and preparing the learning materials that support students to learn science through inquiry which ultimately lead students to construct their own knowledge.

For the NSCS, the inquiry process supports constructivist theory (DCID, 2002) since it is driven by students’ curiosity, interest, and passion in order to understand or to solve their problem. By engaging in the inquiry process, students observe the natural phenomena, raise the questions, design the investigations, search for the information, discuss the data, and communicate the findings to the others. All learning activities are designed to promote students to think critically and logically, to have hands-on action, to formulate the explanation from evidence, and to construct their own knowledge eventually. In the constructivist view, learning is a result of ongoing changes in individuals’ mental frameworks as they attempt to make meaning of the things they experience. In its essence, inquiry leads students to conduct investigations to satisfy their curiosity. Once the curiosity is satisfied, students construct mental frameworks that feasibly explain their experiences (Haury, 1993).

The DCID and the IPST (2002) assist science teachers to incorporate the inquiry process in their classrooms by providing 5Es inquiry process as a guideline of inquiry-based instruction. The 5Es inquiry process comprises of five phases similar to the BSCS 5Es instructional model (Bybee *et al.*, 2006) which are: 1) engagement, 2) exploration, 3) explanation, 4) elaboration, and 5) evaluation. Besides the 5Es inquiry process, the DCID and the IPST also suggests the use of various teaching methods or strategies to promote inquiry teaching, for examples, field work, problem solving, classification and identification, and pattern seeking, etc. Although the DCID and the IPST offers multiple modes of inquiry, they do not give specific prescriptions for teaching science through inquiry in the classroom, so teachers can create modes of inquiry that fit their local classroom situations or their school-based curricula. Thus, the teaching actions of each teacher will necessarily differ based on factors in the local environment, such as teacher knowledge, student ability, and concepts of study.

Statement of the Problems

Despite the fact that teaching science through inquiry has long been promoted in Thailand, its practice throughout the science classrooms has not been fully enacted as recommended (Office of the Education Council, 2001; IPST, 2002). A number of studies consistently report that there is an inadequate usage of scientific inquiry in Thai science classrooms (Ketsing and Roadrangka, 2008; Soparat, 2008; Bongkotphet, 2009; Sangpradit, 2009). Instead of scientific inquiry, a teaching approach that is dominantly found in the classroom is a teacher-centered approach in which teachers mainly rely on explanation, discussion, demonstration, and put less emphasis on hands-on and minds-on activities (Office of the Education Council, 2001; Juntaraprasert, 2009).

According to the literature, the main barriers that impede science teachers' implementation of inquiry-based instruction have been discussed. One of the foremost obstacles is the confusion of science teachers regarding what teaching science through inquiry is and how to transfer the approach into classroom practice (Bybee, 2000; Anderson, 2002; Makang, 2003; Wee *et al.*, 2007). According to Bybee (2000), the term “inquiry” has been defined and used by the science education community in a variety of ways, including the general categories of inquiry as content and inquiry as instructional approach. The National Science Education Standards [NSES] in U.S. (Nation Research Council, 1996) indicates that teaching science through inquiry requires science teachers to have not only science content knowledge, skills necessary to teach inquiry, but more deeply, an understanding of what scientific inquiry is about. Once this understanding is unclear, it will act as a major impact on the adoption and implementation of inquiry-based instruction in science classrooms (Keys and Bryan, 2001; Anderson, 2002; Wee *et al.*, 2007). Thus, to teach science through inquiry, science teacher is initially needed to understand what teaching science through inquiry is about and then trying to apply the knowledge into their teaching practice.

Another significant barrier for enactment of inquiry-based instruction is inadequate and limited professional development programs to support science teachers (Keys and Bryan, 2001; Anderson, 2002; Roehrig and Luft, 2004; Christensen, 2005). With respect to Thai context, Pillay (2002) reports that little attention has been given to develop in-service professional development programs for Thai teachers. Pillay claims, prior to the Thai education reform, many Thai teachers do not attend any teacher professional development programs and the ones who have had some professional development experiences have not enrolled any professional development courses since they graduated from their teacher preparation programs.

With regard to the approach of professional development used in Thailand, Pillay (2002) and Yutakom and Chiaso (2007) reported that most in-service teacher professional development programs in Thailand were designed based on a classic approach. According to their reports, teachers were presented with new concepts and demonstrated with new methods by outside experts (i.e., university academics). The professional development is usually held at a central hall, which requires a high expense for some teachers to attend the program. In addition, many teachers have to leave their class for attending the program. Moreover, the professional development programs do not have continuous assessments for teacher's performance or understanding during or after the programs (Pillay, 2002; Puntumasen, 2004). Due to the fact that the program is a lecture-based program; teachers only listen to the talks without having a practice. They simply follow a new set of teaching approaches. After the program was finished, teachers could not utilize the new approaches in their actual classrooms. As a result, an alternative approach is needed for the professional development which is effective in enhancing teachers' understandings and practices of inquiry-based instruction in their actual classrooms.

According to the National Research Council (1996), professional development that is effective to advance teachers' knowledge and the use of inquiry should include some features that promote lifelong learning. These features are 1) providing numerous opportunities for teachers to examine and reflect on their instructional practices from both each individual and their colleagues; 2) giving some chances for teachers to receive feedback about their practices and to understand, analyze, and apply the feedback to improve their practices; 3) providing opportunities for teachers to experience various tools and techniques for self-reflection and collegial refection; 4) promoting the sharing of teacher expertise through the use of mentors, teacher adviser, coaches, lead teachers, and resources teachers; 5) giving chances for teachers to access to existing research and empirical knowledge; and 6) providing opportunities for teachers to learn and utilize skills of research to generate new content knowledge and pedagogical content knowledge. In this regard, professional development program is related to teacher's life in school, provides opportunities for teachers to learn through designing, implementing, and reflecting on their instructional practice. In addition, it is involved teachers to take responsibility for their own professional development and usually extends beyond the boundary of a short-time workshop. Regarding to these features, teachers are able to continually develop their understanding and practice of inquiry-based instruction as a result of practicing inquiry in their real contexts.

In agreement with the National Research Council (1996), a number of desirable features of professional development programs in Thailand have been highlighted. The Office of the Education Council which is a government agency responsible for educational policy and planning has introduced the School-Based Training [SBT] as a new approach for in-service teacher professional development (Office of the Education Council, 2004; Puntumasen, 2004). There are a number of principles underpinning this approach including: relating to real situation and actual needs of teachers and schools; taking place in teacher's actual context; being part of the teacher's normal practice in school; involving teachers' willingness to engage in the program; promoting the sharing of teacher expertise of lead teachers; providing opportunities for teachers to plan and carry out the program; providing opportunities for teachers to use various teaching techniques, materials, media and activities; providing opportunities for teachers to have opening communication regarding instructional practice both individually and collaboratively; using the recurrence of planning, doing, checking, and acting cycle; promoting teachers to use outcome or feedback obtained from each cycle to improve their practice of the next cycle; supporting the use of supervision, monitoring and evaluation; and aiming to reach the quality and standard of teaching profession as well as students' capabilities.

Several effective features of professional development program provided by both the National Research Council (1996) and the Office of the Education Council (Puntumasen, 2004) is incorporated numerous basic elements of action research (Kemmis and McTaggart, 1988, 2000) and collaborative action research (Oja and Smulyan, 1989) which include a) focus on practice, b) emphasis on professional development, c) self-reflection, d) democratic project leadership, e) time and support for opening the communication, f) collaboration, and g) recurrence of action-reflection cycle. According to Kemmis and McTaggart (1988: 5), action research is defined as:

> a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or education practices, as well as their understanding of these practices and the situation in which these practices are carried out.

For Kemmis and McTaggart (1988), collaboration is a fundamental feature of action research which must be conducted by a group of people who have shared concerns about topic of study (Kemmis and McTaggart, 1988). The aim of collaboration is to change and improve the situation in which the research is carried out. Action research focuses on practitioners' problems and centers on the classroom or the actions of practitioners in situation (Oja and Smulyan, 1989). Thus, the action research supports teacher's efforts to make changes, to solve their own problems, and to improve classroom practice (Darling-Hammond, 1996; Briscoe and Peters, 1997). In addition, it helps teacher to enrich their teaching profession (Oja and Smulyan, 1989). By doing action research, teachers gain new knowledge which helps them solve immediate problems, broaden their knowledge base as professionals, and learn research skills which can be applied to their teaching (National Research Council, 2000). Hence action research involves teachers into lifelong professional development through the support, collegiality, and collaboration of professional researchers.

Many studies consistently reveal that action research and/or collaborative action research is an effective approach for professional development (Zuber-Skerritt, 1991; van Driel, Beijaard, and Verloop, 2001; Balach and Szymanski, 2003; van Zee, Lay, and Roberts, 2003; Jeanpierre, Oberhauser, and Freeman, 2005; Yutakom and Chaiso, 2007). According to Briscoe and Peters (1997), collaborative action research increases teachers' ability to analyze and improve classroom practice and it helps to increase job satisfaction. A study by van Zee and her colleagues (2003) has shown that a collaborative partnership between pre-service teachers and their mentor teachers facilitates pre-service teachers' self-perceptions, teaching science through inquiry, and taking ownership of their own learning. Similarly, Balach and Szymanski (2003) use collaborative action research as a tool to support the development of a professional learning community, and to provoke pre-service teachers with an inquiry approach to their practices. These findings indicate that the study helps pre-service teachers to develop their intellectual capabilities. It also helps participants at all levels to become aware of how to create a context that supports any change. According to Christensen (2005), collaborative action research is a feasible way of changing teacher practice. It helps teachers to promote scientific inquiry in laboratory lessons. In conclusion, action research stands to be an appropriate form of professional development in terms of improving teachers' understanding of inquiry and practicing of inquiry-based instruction.

In this study, a professional development program, known as the collaborative action research program [CAR Program], was established. The CAR Program aims to promote three case study science teachers' understandings and practices with respect to inquiry-based instruction [IBI] in their actual classrooms. This program was characterized by the desirable features of teacher professional development in Thailand which include: a) having long-term support for teachers both in groups and as individuals, b) conducting in teachers' actual classroom, c) encouraging teachers to change their practice, d) being part of the teachers' regular duties, e) promoting collaboration between teachers and the program facilitator, f) empowering teachers' sense of ownership, g) requiring teachers' willingness, and h) working in a friendly atmosphere (Office of the Education Council, 2004; Puntumasen, 2004). The CAR Program was also designed based on the basis of action research (Kemmis and McTaggart, 1988, 2000; Zuber-Skerritt, 1991) and collaborative action research (Oja and Smulyan, 1989), which included: a) focus on practice, b) emphasis on professional development, c) self-reflection, d) democratic project leadership, e) time and support for opening communication, f) collaboration, and g) recurrence of the action-reflection cycle.

By engaging in the CAR Program, the three teachers learned to change their understandings and practices with regard to IBI through the three time repetition of the collaborative action research cycle (also referred to as the action-reflection cycle) and attending a number of meetings with the collaborative action research team [CAR Team], both in the central meeting site and in the teachers' schools. In each action-reflection cycle, individual teachers plan, act, observe, and reflect on their own instruction. After complementing each cycle, the three teachers bring their lesson plans and teaching experiences, as well as problems/concerns to share and reflect with the CAR Team in the central meting in order to reach a complete understanding and full practice of IBI. Consequently, the teachers take an active role in their learning and working with each other during the central meeting while the researcher's role is to facilitate and assist individual teachers in their learning of IBI through the work in the action-reflection cycle and the meetings of the CAR Team.

Research Aims

The aims for taking this study are to enhance Thai science teachers' understanding and practice of inquiry-based instruction [IBI] in their actual classrooms and to explore the efficacy of the professional development program on the enhancement of the three case study teachers' understandings and practices of IBI. The study is shaped by the following research questions.

Research Questions

1) What are the Thai science teachers' understanding and practice of inquiry-based instruction before they engage in the collaborative action research program?

2) What are the Thai science teachers' understanding and practice of inquiry-based instruction after they engage in the collaborative action research program?

Summary of Research Methodology

The methodology employed for investigating the change of teachers' understandings and practices about IBI was interpretive methodology which was framed by qualitative research. The method of the study was qualitative case study, which consists of three male science teachers who taught at lower secondary level (7^{th}–9^{th} grades) in two schools participated in the Project for Extension Opportunity at Lower Secondary Level [EOLS Project]. Data were collected from multiple sources, including individual interviews with the teachers regarding their understanding of IBI, teacher's inquiry-based lesson plans, teacher's written reflections on their teaching, classroom observations, and central meetings of the CAR Team. The data was initially evaluated through a within-case analysis and then follow by a cross-case analysis. The results were reported in individual cases and followed by common findings across the three cases. A detailed account of the methodology is provided in Chapter III.

Definition of Terms

Inquiry-based instruction [IBI] is referred to a teaching approach in science subject that comprises of four aspects of its essential features involving the role of the teacher, the role of the students, the instructional objective, and the instructional process. These essential features are derived from the goals of science teaching and learning, the role of teachers and students in science classroom, and the inquiry-oriented activities suggested by the NSCS (DCID, 2002: 3, 35-36), the 5Es inquiry process guided in the Manual of Science Teaching and Learning (DCID and IPST, 2002: 79-80), the scientific inquiry defined by the NSES (National Research Council, 1996: 23) and the essential features of classroom inquiry (National Research Council, 2000: 24-27) as well as the participating teachers' prior knowledge about IBI (see Activity II in the first central meeting in Chapter III). The aims for having these essential features are to guide the teachers in planning, implementing, observing, and reflecting upon their IBI and to provide the researcher a framework for conducting interviews, classroom observations, and data analyses. A brief description of the essential features of IBI is provided in Table 4.1 in Chapter IV.

Collaborative Action Research Program [CAR Program] is a professional development program established in this study. It aims to enrich lower secondary level science teachers' understanding and practice of IBI in their own classrooms. The program is designed based on a number of principles consistent with the desirable features of teacher professional development program in Thailand. These features include: a) having long-term support for teachers both in groups and as individuals, b) conducting in teachers' actual classroom, c) encouraging teachers to change their practice, d) being part of the teachers' regular duties, e) promoting collaboration between teachers and the program facilitator, f) empowering teachers' sense of ownership, g) requiring teachers' willingness, and h) working in a friendly atmosphere (OEC, 2004; Puntumasen, 2004). The CAR Program is also developed according to fundamental characteristics of action research (Kemmis and McTaggart, 1988, 2000; Zuber-Skerritt, 1991) and collaborative action research (Oja and Smulyan, 1989), which include: a) focus on practice, b) emphasis on professional development, c) self-reflection, d) democratic project leadership, e) time and support for opening the communication, f) collaboration, and g) recurrence of action-reflection cycle.

Collaborative Action Research Team [CAR Team] is referred to five persons who were involved in the CAR Program. The CAR Team comprised of three science teachers who taught at lower secondary level, one researcher, and one science educator. The team members had a shared goal. Their goal in common was to promote the science teachers' understanding and practice of IBI in their real classrooms. The CAR

Team was scheduled to meet often throughout the CAR Program. The meetings were held at both the central meeting site (Faculty of Education) and at each teacher's school. The meetings at the central meeting site were known as "central meetings", whereas the meetings held at the teachers' schools were known as "one-to-one meetings". Hence, the "CAR Team" term used in this study referred to not only when all members of the team met at the central meetings, but also when individual teachers worked with the researcher in the one-to-one meetings.

Limitation of the Study

Research Site

This study was taken place in two public lower secondary schools participated in the Project for Extension Opportunity at Lower Secondary Level [EOLS Project] in Bangkok. The schools are governed by the Department of Education Bangkok Metropolitan Administration [BMA].

Participants

This study comprised of three males science teachers who taught general science subject at lower secondary level (7^{th}-9^{th} grades) in two schools participated in the EOLS Project during the 2008 academic year. The three teachers were purposefully selected based on three criteria: participants' willingness to be involved in the professional development program, their lacked of opportunities to participate in other professional development programs/workshops in relation to IBI during the past three years (2004-2006), and their school's location were located nearby the central meeting site (Faculty of Education).

Organization of This Thesis

This study comprises of six chapters. The Chapter I delineates the background of the study and statement of the problems along with a brief overview of research aims, research questions, and research methodology. In addition, this chapter includes a definition of terms important to the study and a limitation of the study. The Chapter II describes review of the literatures. These include a) context of the study; b) scientific inquiry; c) professional development; and d) relevant studies. The Chapter III provides discussions of the overall research methodology and methods used to address the research questions. This chapter contains four sections. The first section describes qualitative research, interpretive methodology, case study method, as well as the rationales. The second section provides context of the study including research sites, participants, and the CAR Program. The third section describes data collection methods and data analytical procedures. Finally, the last section addresses all techniques utilized in this study to ensure its trustworthiness. The Chapter IV illustrates the results of the study in relation to the first research question. This chapter begins with an explanation of the essential features of IBI. It is followed by individual teacher's background information, the results of the teachers' understanding and practice regarding IBI before the CAR Program, the common findings across the three case study teachers, and the discussions of the findings. The Chapter V provides the results of the study in relation to the second research question: the teachers' understanding and practice of IBI after the CAR Program. The results are initially reported in individual cases and followed by common findings across the three cases. Finally, the discussions of the results are provided. The Chapter VI provides the conclusions and implications of the findings of the research study.

CHAPTER II

REVIEW OF LITERATURE

Introduction

This study aimed to explore the changes of three lower secondary level science teachers in terms of their understandings and practices of inquiry-based instruction [IBI] as a result of their participations in the professional development program, entitled the collaborative action research program [CAR Program]. The current chapter provides a review of the literature related to the study. The scope of review of literature includes a) context of the study, b) scientific inquiry, c) professional development, and d) relevant researches.

Context of the Study

To provide a greater understanding of science teaching and learning in Thai context, the framework of science instruction specified in the Thai government statements is discussed mainly in this section. In addition, the background information of the schools involved in the study as well as the features of professional development in Thailand are described.

Framework for Science Instruction in Thai Context

During the period of this study (academic year 2008), teaching of a science subject at lower secondary level was complied with the National Science Curriculum Standards [NSCS] (DCID, 2002; IPST, 2002) and the guidelines of science instruction described in the Manual of Science Teaching and Learning (DCID and IPST, 2002). Therefore, the following section provides a framework of science instruction suggested in this two government statements.

Science Teaching and Learning in the National Science Curriculum Standards

According to the enactment of the National Education Act 1999, the DCID and the IPST has responded to the government policy by launching a science core curriculum, so-called “the National Science Curriculum Standards [NSCS]”, in order to set standard criteria for teaching and learning the science subject (DCID, 2002; IPST, 2002). According to the NSCS, students are expected to learn science not only science content knowledge but also science process skills, scientific attitudes, and attitude toward science. As mentioned in the NSCS:

> Learning of science should be a developmental process so that the learners could acquire proper knowledge, process, and attitude. All learners should be properly motivated to learn a science subject with their interests and enthusiasms. Additionally, the learners should also be curious and eager to explore the naturally surrounding world, should be determined, and should appreciate about conducting a research and searching for new knowledge. Moreover, they should be capable of collecting the data, analyzing the results to answer the specific questions, presenting and discussing the obtained data and findings with the others (IPST, 2002: 3).

According to the NSCS, eight main areas in science subject, which are so-called “science strand”, include: 1) Living Organisms and Processes, 2) Life and Environment, 3) Matters and Properties, 4) Force and Motion, 5) Energy, 6) Origin of the Earth, 7) Astronomy and Space, and 8) Nature of Science and Technology. The NSCS is designed as a spiral curriculum which the concepts in each strand are firstly introduced at the primary level, and re-introduced at a higher degree of knowledge through the lower secondary level and the upper secondary level, respectively. The strand 8^{th} is expected to be integrated into the contents of strands 1^{st} – 7^{th}. In addition, scientific inquiry must be incorporated as an essence of the nature of science.

According to science instruction, the NSCS provides the goals of teaching and learning science. With regard to the NSCS, the learners who complete 12 years of basic education should:

1) Understand the principles and theories in basic science.
2) Understand the scope, nature and limitations of science.
3) Be able to acquire knowledge and to solve the problems in science and technology.
4) Develop a thinking process, imagination, and abilities to solve a problem, manage the data, communicate with each other, and make a decision.
5) Realize the relationships between science, technology, humanity, and environment in terms of the influence and impact on each other.
6) Apply the knowledge regarding science and technology for the benefits of their societies and daily lives.
7) Have the attitudes, moral, ethics, and appreciations to utilize science and technology productively (DCID, 2002: 36).

Consequently, the goals of teaching and learning science do not limit only science content knowledge, but they are also set toward the skills, abilities, and attitudes. To achieve these goals, the NSCS suggests that science teachers should change their roles from the lecturers or transmitters to the planners or facilitators who support or facilitate student's leanings by designing the learning activities, posing the questions, giving the advices, and preparing the learning materials (DCID, 2002). In addition, teachers should encourage students to be active investigator in learning activities. Students should be involved in hands-on investigations and in sharing and making decision regarding learning activities.

The NSCS emphasizes that science teaching should focus on the inquiry process which encourages students to construct their own knowledge. By engaging in the inquiry process, students observe the natural phenomena, raise the questions, design the investigations, search for the information, discuss the data, and communicate the findings to the others. All learning activities are designed to promote students to think critically and logically, to have hands-on action, to use an inquiry process, to formulate the explanation from evidence, and to construct their own knowledge eventually.

Finally, the NSCS (DCID, 2002) describes three types of inquiry process that have been promoting in the science classrooms including structure inquiry, open-ended problem, and science and technology project. The review of these types of inquiry is provided in the section of scientific inquiry of this chapter.

Science Instruction in the Manual of Science Teaching and Learning

For guiding the teachers to design their teaching and learning activities, the DCID and the IPST have issued the Manual of Science Teaching and Learning in the same year of issuing the NSCS. According to the manual, teaching and learning activities should be designed based on a learner-centered approach which is compatible with the constructivist’s view of learning (DCID and IPST, 2002). According to the constructivism, learning is a self-regulating and socially mediated (Sivan, 1986). Learners have to engage in and interact with the environment (e.g., learning activities, peers, or a teacher) in order to construct their own knowledge. In the constructivist’s perspective, learners are active participants who play a major role in the learning process.

For implication of the constructivist’s perspective on the learning in science teaching, science teachers should realize that students come to the classroom with their conceptual knowledge. Students do not learn the lesson just by listening to teacher’s teachings and transmitting the information into their brains. Rather they construct and acquire their knowledge by interacting with the surrounding nature. Thus, teachers should design teaching and learning activities that encourage students to conduct some investigations, look for the information, and relate the new information to their existing knowledge.

The manual also indicates that science subject should be taught through the inquiry process (DCID and IPST, 2002). In order to teach and learn sciece through this process, the manual provides 5Es inquiry process as a guideline for science teachers. The 5Es inquiry process comprises of five phases similar to the BSCS 5Es instructional model (Bybee *et al.*, 2006) which involve: 1) engagement, 2) exploration, 3) explanation, 4) elaboration, and 5) evaluation. In the engagement phase, teacher introduces students to the question(s) or problem(s) to be investigated. Thus, teacher designs a short activity that motivates students' curiosity. Teacher usually elicits students' prior knowledge and skills during this phase. In the exploration phase, teacher provides an opportunity for students to design investigation, formulate hypothesis, and collect data. According to the manual, there are several methods of investigation can be employed such as experiment, field work, simulation, and reviewing information from reliable resources. In the explanation phase, teacher teaches students to analyze the data, interpret their findings, and formulate an explanation or conclusion. In this phase, students have a chance to present their findings to their friends. In the elaboration phase, teacher links the new knowledge and skills obtained from the investigational process to students' prior knowledge. In addition, teacher may elaborate students' knowledge and skills by giving a new situation that requires students to apply the same knowledge and skills. In the evaluation phase, teacher assesses students' knowledge obtained from the lesson in order to evaluate students' learning ability and capability.

In addition to the 5Es inquiry process, the manual also suggests the use of various teaching methods to promote inquiry, for examples, field work, problem solving, classification and identification, and pattern seeking, etc. (DCID and IPST, 2002). However, unlike the 5Es inquiry process, the manual does not provide steps of instruction for these modes of inquiry; so that teachers have to create the modes of inquiry that suit their classroom circumstances.

Project for Extension of Educational Opportunity at Lower Secondary Level in Bangkok

This study was conducted on a group of science teachers who taught at the lower secondary level (7^{th}–9^{th} grades) in two schools in Bangkok. These schools participated in the Project for Extension Opportunity at Lower Secondary Level (also known as the EOLS Project) which was launched by the Department of Education Bangkok Metropolitan Administration [BMA]. The following parts provide a brief description of the schools participated in the EOLS Project and the problems with teaching and learning science found in these schools.

General Description of the EOLS Project

Although several schools in the remote areas participated in the EOLS Project, this section focuses only on the EOLS project which was launched in Bangkok in 1992. The ultimate goal for launching this project is to provide education opportunities for Thai children to study at lower secondary level, particularly those who from low income families and those whose houses are located far from secondary schools. Another goal of the EOLS Project is to increase a number of lower secondary schools in order to advance the government's policy for extending compulsory level education from elementary level to lower secondary level. Prior to the year 1999 (the year of Thai educational reform), compulsory education in Thailand was limited only at the elementary level. As a consequence, many students who completed elementary school had to drop out from basic education (1^{st}–9^{th} grade). This issue reinforced the enactment of the EOLS Project. To accomplish these goals, the EOLS Project has provided a financial support, instructional media, and an administrator/teacher professional development for the elementary schools participate in this project for opening three more years of education (7^{th}–9^{th} grades). Therefore, the elementary schools have developed into lower secondary schools which compose of children from 1^{st} grade to 9^{th} grade. As a result, students who complete elementary level are able to study at the lower secondary level in their schools. However, the challenge of the EOLS Project is to motivate students to complete the lower secondary level of education. The EOLS Project encourages student enrollment by providing education free of charge. Every schools involved in this project are financially supported from the BMA. Students also receive free textbooks, learning materials, uniforms, a lunch meal, and in some cases an accommodation. Moreover, some schools offer the good opportunity for students by opening vocational classes and supporting part-time jobs.

In the beginning, there were only four schools in Bangkok participated in the EOLS Project; however, the number of participated schools has increased every year. Since 1998, the EOLS Project has extended to higher secondary level. At the time of this study (2008), there were 90 schools in and around Bangkok city joined this project: 85 schools had the grade 1^{st} to 9^{th}, 4 schools had the grade 7^{th} to 12^{th}, and only one school had the grade 1^{st} to 12^{th}.

Problems of Teaching and Learning Science in Schools Participate in the EOLS Project

Several studies have reported some problems and obstacles regarding teaching and learning science found in schools participated in the EOLS Project. Meinoratha (1997) studied science instruction at lower secondary level in the schools participated in this project using a questionnaire to collect the data from 48 science teachers from 44 schools in and around Bangkok. All of the questionnaires were returned and analyzed. The findings showed that a number of problems related to science teaching and learning such as: 1) schools did not have teachers whose major in science (87.5%), 2) some teachers lacked of pedagogical content knowledge in teaching science (60.4%), 3) some teachers lacked of science content knowledge and process skills (29.2%), 4) many teachers were work load (66.7%), 5) some teachers did not have time to design the lesson plans (41.7%), 6) students did not have enough time to study science because schools had too many activities (87.5%), 7) some students had low responsibility in learning (33.3%), 8) some students had low motivation to learn science (31.3%), and 9) there were too many expected learning outcomes in science core curriculum (56.3%). However, the study of Meinoratha showed that all of these science teachers usually designed the lesson plan, identified teaching and learning purpose, prepared the instruction, used experiments in classes, and motivated students to discuss the data obtained from the experiment.

Similar with Meinoratha (1997), BMA (1999 cited in Singdumrong, 2000) also reported the common problems found in the schools participated in the EOLS Project such as: 1) schools did not have enough teachers, particularly whose major in specific subject areas (e.g., science, mathematics, etc.), 2) teachers did not teach in subject areas of their expertise, 3) teachers did not have the content knowledge, skills, and expertise in teaching lower secondary level students, 4) teachers did not fully understand about the structure of curriculum in lower secondary level, and 5) students had poor motivation to study.

In 2000, Singdumrong conducted a survey regarding the needs for professional development of 350 teachers who taught in 55 schools participatied in the EOLS Project in Bangkok. The data was gathered from 340 (97.1%) questionnaires. The results showed that topics for professional development that the teachers needed in highest level (3.21-4.00) were: 1) using curriculum and teacher manual productively (4.12), 2) designing lesson plan (4.08), 3) developing content knowledge in subject area (4.04), 4) teaching through learner-centred approach (4.06), 5) creating positive classroom atmosphere (4.05), and 6) producing instructional media (4.11). The study also reported the needs of the teachers regarding approaches of professional development. Their demands in hightest level included: 1) action research (4.03), 2) group discussion (4.00), 3) workshops (3.99), and 4) Computer Asisted Instruction [CAI] (4.24). In terms of time and place for conducting professional development, the majority of teachers wanted the professional development to take place at their schools (77.0%) and allow them to attend during schools brake (62.9%).

In academic year 2005, Bongkotphet (2009) conducted an in-depth interview with three science teachers in a school participated in the EOLS Project regarding their knowledge for teaching astronomy through inquiry. The results showed that these science teachers usually taught astronomy by using a lecture, a discussion, and an observation. For the view point of teachers, teaching through inquiry was to have children search information, do report, and then present what they found among each others. All three teachers agreed that inquiry teaching was beneficial to their students because it enhanced students' abilities to search the information as well as to think critically. However, this approach was limited because: 1) it took too much time; 2) it was suitable only for those students who had good responsibility; and 3) it could be employed only if students had the learning resources at home (e.g., the internet).

The recent study by Sangpradit (2009) investigated the current state of teaching and learning on "the concept of light" in academic year 2005. This research was conducted on 37 science teachers in the schools participated in the EOLS Project by using a questionnaire. The results showed that all 37 teachers followed school curriculum based on the NSCS. Typically, the teachers spent 2-10 hours per week for preparing the lessons. With regard to instructional process, most teachers began their teachings by discussing the concepts obtained from the previous lesson and sometimes by having students did a pretest which could encourage the students to think and prepare for the current lesson. The most common methods for teaching the concept of light were the lecture and experiments. In addition, Sangpradit reported the common problems from majority of these teachers were: 1) lacking of the content knowledge (81%), 2) lacking of the knowledge in writing the lesson plan (57%), 3) lacking the knowledge of new teaching strategy (81%), and 4) lacking of the instructional materials and learning resources (81%).

A year later, Ketsing and Roadrangka (2008) studied the current state of teaching and learning on the topic of "the unit of ecology" in academic year 2006 at 58 lower secondary schools involved in the EOLS Project using a questionnaire. Thirty-four questionnaires (58.6%) were analyzed. Similar to the findings of Bongkotphet (2009), Ketsing and Roadrangka found three common teaching methods used in this topic were a field trip, a discussion, and a lecture. Only few teachers taught ecology through an inquiry and experiments. However, they found that the majority of these teachers (91.2%) understood that inquiry was a teaching method that led students to construct their own knowledge and students played an active role in inquiry-based classroom. The common problems in teaching this topic, in some extent, similar to those of Meinoratha (1997), BMA (1999 cited in Singdumrong, 2000), Bongkotphet (2009), and Sangpradit (2009). The problems of teaching ecology included: 1) teachers had insufficient of instructional aids and media (50.0%); 2) teachers did not have the knowledge in teaching technique and method (7.7%); 3) students were uninterested in ecology (23.5%); 4) there were too many students in the class (3.8%); and 5) the expected learning outcomes in school's curriculum were too many (3.8%).

With regard to science achievement of students, BMA (2004) reported the majority of students at lower secondary level in schools participated in the EOLS Project had relatively low achievement in science subject. Approximately, forty percent of them achieved science in the level 1 which meant they had score in science between 50 and 59 (out of 100). In addition, approximately ten percent of them did not pass science subject indicating that they had a score in science lower than 50. As a result, these students had to restudy this subject.

In summary, there are a number of problems regarding science instruction in schools engaged in the EOLS Project. Most of the problems are related to the competency of teaching among science teachers. Thus, in order to improve the quality of education, science teachers need to improve the capability and skills of teaching (Atagi, 2002). It is generally accepted that teachers play a significant role in developing the quality of learners (Puntumasen, 2004; Roadrangka, Yutakom, and Chaiso, 2008). According to the literature, teachers usually teach science subject through a discussion, a lecture, and an experiment. Teachers view inquiry as a useful approach but in practice they are likely to choose lecture or discussion instead of inquiry. Therefore, it is a need for encouraging science teachers to understand and teach science through inquiry. In this regard, professional development program is emphasized as a way to promote inquiry in science classroom.

The following section describes approaches of professional development that are generally utilized in Thailand. It is followed by the rationale for seeking a new approach for professional development. The section is then completed by the descriptions of desirable features of professional development that are viewed as effective in enhancing teachers’ understanding and practice in relation to learner-centered approach.

Teacher Professional Development in Thailand

Three Approaches of In-service Teacher Professional Development

Prior to the enactment of the 1999 National Education Act, the most in-service teacher professional development in Thailand were typically organized by the central agencies such as the supervisory units of the Ministry of Education and the IPST. The professional development was usually held at a central hall or a hotel, which was a high expense for some teachers to attend the program/workshop. In general, the professional development programs were lecture-based programs. Teachers just listened to the talks without practice. In addition, some teachers might leave their class while attending the program/workshop. The program/workshop was usually held for 2-3 days with no continuous assessment for teacher’s performance or understanding during and after the program/workshop (Pillay, 2002; Puntumasen, 2004).

In general, there are three approaches of in-service teacher professional development commonly used in Thailand such as: 1) a workshop, 2) a developing master teacher, and 3) a long distance teacher development [ETV]. For the first model, teachers have to attend a workshop to receive new concepts or teaching methods by outside experts. The workshop is usually organized by some university researchers and conducted in a short period of time without any continuing supports from outside experts. In adition, teachers do not share any ideas regaring the design of the workshop (Atagi, 2002; Pillay, 2002). For the second approach, master teachers are trained and commited to be the leaders for training other teachers in their school areas or districts. The “master teachers” reffer to the teachers who are expert in the new concept or teaching method that they have learnt from professional development program/workshop (Pillay, 2002). Thus, this approach usually begins with a short-time workshop in order to create master teachers. In some cases, the master teachers and other teachers in schools or local areas form a “learning community” where they could share and exchange the ideas related to the new concepts or methods. Generally, this approach of professional development has continuous supports from the external researchers. Nevertheless, the professional development programs are modulated by the outside experts rather than the participated teachers per se. Therefore, the new concepts or teaching methods may or may not relate to what teachers want to know. For the last approach of professional development, the programs are conducted via a distance education. Teachers learn new concepts or methods by watching master teachers’ teaching on a television. This approach is mostly beneficial for the teachers in rural areas even though it does not allow them to actively engage in the programs.

Rationale for Seeking New Approach of Teacher Professional Development

According to the 1999 National Education Act and Amendments, both constructivist perspectives and learner-centered approach are centralized in Thai basic education (ONEC, 2003). The pedagogical practices have been shifted from teacher-centered toward learner-centered pedagogy. The role of teachers has also been changed from a lecturer to a facilitator. Instead of lecturing students, teachers become the facilitators who support students’ learning by designing meaningful activities, posing the questions, giving the advices, and preparing the learning materials (DCID, 2002). To achieve the new role, teachers need to have more knowledge and skills in teaching (Pillay, 2002). In addition, their teaching professions need to be continuously developed. It is suggested that the teacher professional development that is organized by outside school agencies; rely mainly on the lecture; require teachers to leave their classes while attending the program; be held in a very short-time period; and do not provide the continuous supports for teachers have to be changed (Unesco, 1986; Pillay, 2002; Office of the Education Council, 2004). Since these approaches of professional development are not designed based on teachers’ needs or interests, the programs are unable to foster the teachers’ sense of ownership. They take teachers out of the classroom (Unesco, 1986). The teachers could not implement these new approaches once they return to their actual classrooms. Although some teachers might want to employ the new approaches in their classes, they could not do this because neither the program nor anyone could provide a long-term support. Moreover, the professional development programs that rely mainly on a lecture do not promote teachers to construct their own knowledge and do not provide an opportunity for teachers to think critically on their practices. These professional development programs are not aligned with the constructivists' perspective on learning. Therefore, an alternative approach for professional development which allows teachers to play an active role in enriching their teaching profession is urgently required.

Desirable Features of Professional Development

Recently, desirable features of professional development programs in Thailand have been highlighted. The Office of the Education Council which is a government agency responsible for educational policy and planning has introduced the School-Based Training [SBT] as a new approach for in-service teacher professional development (Office of the Education Council, 2004; Puntumasen, 2004). There are four projects launched by the Office of the Education Council in order to study the effectiveness of the SBT approach. The findings from these studies suggest that the SBT is an effective and sustainable approach for developing in-service teachers in their teaching profession which it contributes to the learner-centered approach of Thailand education reform (Puntumasen, 2004). There are ten principles underpinning the SBT:

1) Professional development must be based on a real situation and actual needs of both schools and teachers.

2) Professional development should be held at the school (school-based) or at the community (community-based);

3) The teachers' competencies are augmented by the teachers or groups of teachers, who are leaders of learning reform. The leaders have the expertise and experience in SBT teacher development;

4) Professional development involves participates' willingness;

5) Program facilitators and teachers should work together to conceptualize, plan and carry out the professional development program;

6) Professional development involves actual practice, utilizing different teaching and learning methodology, training materials, media and activities, which will be applied to actual classroom situation;

7) Professional development should involve group meetings and individual consultations in order to find solutions to problems and to enhance the students' learning;

8) Professional development should follow the PDCA process which comprises of planning, doing, checking, and acting, respectively. It is an on-going process and uses the evaluation outcomes as a feedback to improve the planning;

9) Professional development should use a supervision, a monitoring and an evaluation. The evaluation is based on both the outcomes of professional development program and learning achievements of the students in teacher's classroom;

10) Professional development should be a part of the teacher's regular activity and its ultimate aims are to raise the quality and standard of teaching profession as well as students' capabilities (Puntumasen, 2004: 3).

Atagi (2002) summarizes a lesson-learned from a number of pilot projects for preparing in-service Thai teachers and school administrators to utilize a learner-centered approach. Atagi points out the key success factors of the pilot projects which involved 1) the continuity and sustained efforts, 2) the stakeholder participation and collaboration, and 3) the supportive mechanisms. For the first factor, Atagi claims that the programs must provide continuity and sustained efforts for supporting their participants in implementing the new approach. The program facilitators have to support the participants both in the workshops and once the participants return to their schools. In the second factor, Atagi indicates that it is very important to have all stakeholders participate and collaborate in the projects. For him, the participation refers to the inclusion of all stakeholders in providing ideas and joining in implement efforts. Collaboration means the need for different stakeholders to agree on the certain approaches and work together to implement the approaches. With regard to the last factor, Atagi mentions that the successful projects are required the supports from both central education agencies and on-site facilitation following the training programs. Atagi claims without both supports the participants do not have the confidence to make change.

For Pillay (2002), he suggests that there is a need for professional development in Thailand that focuses on shifting teacher's beliefs on their practices. Pillay considers action research as a significant component that should be embedded in teacher professional development. Pillay argues action research could enhance teacher's capability to develop their competencies which is essential for teaching through a student-centered approach.

In summary, the new approach of in-service teacher professional development should include the following features : 1) a long-term support for teachers both in groups and individuals, 2) conducting in teacher's actual classroom, 3) encouraging teachers to change their practices, 4) being a part of the teacher's regular duty, 5) promoting collaboration between teachers and program facilitator, 6) empowering teachers' sense of ownership, 7) requiring teachers' willingness, and 8) working in a friendly atmosphere.

The following section provides a discussion of scientific inquiry which includes: general description of scientific inquiry, scientific inquiry in terms of learning outcome and teaching approach, inquiry-based instruction [IBI], and framework of IBI utilized in this study.

Scientific Inquiry

General Description of Scientific Inquiry

Virtually, there is no consensus regarding the meaning of scientific inquiry in the filed of science education (Minstrell, 2000; Anderson, 2002; Barrow, 2006; Wee *et al.*, 2007). Minstrell (2000) reveals a number of definitions of scientific inquiry found in the science education community: fostering inquisitiveness; a habit of mind; teaching strategy for motivating learning; hands-on and minds-on activities; and manipulating materials to study natural phenomena and answer question. However, Minstrell (2000: 472) points out many instructors accept that “[scientific] inquiry means different things to different people” and “to understand inquiry, we [science educators] need to identify the various aspects of the process and see them as a whole.” According to Minstrell, inquirer should learn something new when he/she is doing scientific inquiry. Even though investigation fails to answer question, at least inquirer should know factors that are not involved in the solution.

Novak (1964: 26) defines that “inquiry is the [set] of behaviors involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious.” For Novak, “scientific inquiry is a way of investigating problems via the mind, the senses, and the mechanical or electronic extensions thereof.” Similar to Novak, Welch *et al.* (1981) consider inquiry as a general process human being use for seeking information or understanding. It is a way of thinking process. Welch and colleagues clarify that scientific inquiry is a subset of inquiry which is located on a natural world and framed by the beliefs and assumptions of inquirer. In agree with Welch *et al.* (1981), Chiapptta and Koballa (2006: 144) view scientific inquiry as a division of inquiry which focuses on natural phenomena and it is typically conducted by scientists. Chiapptta and Koballa also define scientific inquiry as “a creative process that is fueled by curiosity and hard work, often resulting in frustration and sometimes leading to useful knowledge.”

According to the Exploratorium Institute for Inquiry in the U.S. (Exploratorium Institute for Inquiry, 1998), the scientific inquiry refers to “an approach to learning”. By taking this approach, learners are involved in a process of exploring the natural or material world. The approach leads learners to ask questions and conduct investigation in order to reach new understandings. In compliant with the Exploratorium Institute for Inquiry, the Manual of Science Teaching and Learning in Thailand (DCID and IPST, 2002) defines scientific inquiry as the way students employ for searching for scientific knowledge using scientific process(es) or other methods of scientific investigation such as exploration, observation, measurement, classification, experimentation, modeling, and review information from reliable resources.

In summary, different people may think that scientific inquiry is refers to different things; however, there is still an agreement in some aspects of scientific inquiry. Firstly, scientific inquiry focuses on the natural phenomena. Secondly, it is the way that inquirer uses to address his/her question or to gain a better understanding of a particular phenomenon. Thirdly, scientific inquiry is purposefully employed to satisfy the need of inquirers. Finally, inquirer plays an active role in scientific inquiry.

In the field of science education, there are two aspects of scientific inquiry which is generally referred: inquiry as the essence of scientific enterprise and the strategy for teaching and learning science (Rutherford, 1968; Hinrichsen and Jarrett, 1999; Bybee, 2000; National Research Council, 2000; Chiappetta and Koballa, 2006). These two aspects of scientific inquiry are discussed in the section below.

Scientific Inquiry as Learning Outcome and Teaching Approach

It is generally accepted by Rutherford (1964), Hinrichsen and Jarrett (1999), and Chiappetta and Koballa (2006) that there are at least two aspects of scientific inquiry. First, scientific inquiry is referred to the science content or the product of scientific research. Second, scientific inquiry is a technique, method, or strategy for learning science as well as a process of teaching science. In addition, Rutherford (1964), Hinrichsen, and Jarrett (1999) could distinguish these two aspects and viewed inquiry as the essence of scientific enterprise and as a strategy for teaching and learning science.

According to the opinion of science educators, Dewey (1910), Schwab (1960), and Rutherford (1968) agree that science need to be learnt and taught as a process of acquiring knowledge rather than the body of knowledge. They also believe that science subject is understandable when the learners study it through the way in which the knowledge is created or discovered. In another word, learning and teaching science should be employed through [scientific] inquiry. This vision in teaching and learning science has become a main impact on science study in many counties, for instance, United State (National Research Council, 1996), United Kingdom (Woolnough, 2000), Taiwan (Chang and Mao, 1999), Israel (Zion *et al.*, 2004), Singapore (Curriculum Planning & Development Division, 2004) as well as Thailand (DCID, 2002; IPST, 2002).

According to the NSES (National Research Council, 1996), scientific inquiry may refer to various things such as: 1) the ways scientists study the natural world; 2) the activities students do for understanding scientific ideas and how scientists work; 3) expected learning outcomes, and 4) teaching strategies. The NSES (National Research Council, 1996: 23) also states that the activity embedded in inquiry is clarified as:

> Inquiry is a multifaceted activity that involves making the observations, posing the questions, examining the books and other sources of information in order to review what has already been known, to plan the investigations, to gather some experimental evidence, to propose the answers, explanations, and predictions, and to discuss the results. Inquiry requires identification of the

assumptions, use of critical and logical thinking, and consideration of alternative explanations.

National Research Council (2000) and Bybee (2000) indicate that the term "inquiry" is used by the NSES in two meanings. First, it refers to content or learning outcomes in which students are expected to understand about nature of scientific inquiry and to develop abilities necessary to learn science through inquiry. Second, inquiry refers to strategies for teaching and learning science which are associated with inquiry-oriented activities.

According to the Thai context, the term "inquiry" is also used by the NSCS (DCID, 2002) in two aspects similar to the NSES (National Research Council, 1996). The former aspect, the inquiry is an essence in the nature of science. It is addressed in Strand 8: Nature of Science and Technology, as a core basic science that all students are expected to understand and be able to develop the skills essential for learning science through inquiry. Scientific inquiry is implicated in sub-strand 8.1:

> Students should be able to employ scientific inquiry and scientific attitudes in investigating as well as solving the problems. They should know that most natural phenomena are definable patterns which are explainable and verifiable within the limitations of data and instrumentation during the periods of investigation. Students should realize that science, technology and the environment are interrelated to each other (DCID, 2002:11).

In the latter aspect, scientific inquiry is the teaching strategy that enables scientific knowledge to be controlled via the use of scientific investigations. It has been promoting as the central approach for teaching science in Thailand for more than 20 years (DCID, 2002). The Manual of Science Teaching and Learning (DCID and IPST, 2002: 146) provides guidelines for the inquiry teaching process through an instructional model which is known as "the 5Es inquiry process". The 5Es inquiry process consists of 1) engagement, 2) exploration, 3) explanation, 4) elaboration and 5) evaluation. The Manual also indicates other teaching strategies that can support scientific inquiry, including the pattern seeking, cooperative learning, exploring, developing systems, model investigating, and problem solving.

All together, the fundamental meaning of scientific inquiry in both Thai and American educations represents the current consensus on the aspects of inquiry in science. It revolves on two critical aspects, such as 1) the inquiry as an essence of scientific enterprise, and 2) the inquiry as a strategy for teaching and learning science. Students in science classrooms are expected to develop the ability in scientific inquiry and to understand scientific inquiry as the way scientists usually do to acquire the knowledge. Accordingly, a science teacher becomes the key person who guides, assists, and facilitates students in their learning through scientific inquiry. Subsequently, the teacher need to know, at least, what scientific inquiry teaching is and also how to use it in the science classroom (Wee *et al.*, 2007).

Given that the study aims to enhance lower secondary level science teachers' understanding and practice of IBI in their actual classrooms, the following section focuses on scientific inquiry in the aspect of teaching strategies. In addition, the key components of inquiry-based instruction, the level of inquiry-based teaching, and the constraints for implementing this instruction are also addressed.

Inquiry-Based Instruction

Key Components of Inquiry-Based Instruction

Although there is not common agreement regarding the meaning of scientific inquiry, it is generally accepted that inquiry is an effective approach for teaching and learning science when compared to traditional lecture-based approach (Shymansky, 1984; National Research Council, 2000; IPST, 2002). Colburn (2000: 42) defines inquiry-based instruction as “the creation of a classroom where students are engaged in essentially open-ended, student-centered, and hands-on activities.” According to the NSES (National Research Council, 2000: 25), the classroom inquiry should provide the following features:

1) Learners are engaged by scientifically oriented questions.
2) Learners give priority to the evidence which allows them to develop and evaluate the explanations that address scientifically oriented questions.
3) Learners formulate their explanations from the evidence to address scientifically oriented questions.
4) Learners evaluate their explanations in light of alternative explanations, in particularly, those reflecting scientific understanding.
5) Learners communicate and justify their proposed explanations.

National Research Council (2000) states that each feature can be varied depending on the amount of structures, guidance, and coach that teacher provides for the students who engage in inquiry. In addtition, the classroom that has all of these essential features can reflect the full utility of inquiry.

Continuum of Inquiry-Based Instruction

National Research Council (2000) suggests that inquiry can be applied in the science classrooms in various approaches. Investigations can be initiated by the teachers or opened for students' explorations of unidentified phenomena. The degree to which teacher or students forms the investigation relies on the expected learning outcomes. As the learning outcomes themselves vary, all the forms of inquiry can be implemented in a science classroom. National Research Council also advises science teachers to have students experience all types of the inquiries in learning science. It should note that the variation of inquiry is rooted from Schwab's three approaches of science teaching through laboratories. According to Schwab (1960: 9), all of these levels allow students to study phenomena which they do not know before. In the first level, question and method of investigation come from teacher or materials. For the second level, teacher or materials are able to pose question, but the method of investigation have to initiate from students. In the last level, everything is from students whether the question, investigation method, and explanation. Schwab also suggests science teachers to teach science using what he calls "enquiry into enquiry".

By taking this approach, teachers provide scientific research or report for students to read and then discuss the research details.

Tofaya, Sunal, and Knecht (1980 cited in Bell, 2002), Colburn (2000), and the DCID (2002) reveal several forms of inquiry that are able to establish in science classroom. Their classifications are based on the degree to which teacher and student are participated in the investigation. For Tofaya *et al.* (1980 cited in Bell, 2002: 16), there are four types of inquiry, ranging from teacher-directed to learner-directed, including: confirmation activity, structured inquiry, guided inquiry, and open inquiry. Based on Colburn (2000: 42), he defines four kinds of inquiry which are: structured inquiry, guided inquiry, open inquiry, and learning cycle. According to his definition, the first three types of inquiry are similar to those mentioned by Tofaya *et al.* (1980 cited in Bell, 2002). By considering Thai context, the NSCS (DCID, 2002: 37) describes three types of inquiry that have been promoted by the IPST in science classrooms. They are structured inquiry, open-ended problem, and science and technology project. The notions of these three forms of inquiry are in agreement with structured inquiry, guided inquiry, and open inquiry defined by Tofaya *et al.* (1980 cited in Bell, 2002) and Colburn (2000). A summary of type of inquiry in science instruction according to the three literatures is shown in Table 2.1.

Table 2.1 Type of Inquiry in Science Instruction

	Type of Inquiry				
Tafoya *et. al.*:	Confirma-tion activity	Structured inquiry	Guided inquiry	Open inquiry	---
Colburn:	---	Structured inquiry	Guided inquiry	Open inquiry	Learning cycle
DCID:	---	Structured inquiry	Open-ended problem	Science and technology project	---
Component of inquiry process	Generated by Teacher (T) -- Student (S)				
Posing question	T	T	T	S	S
Planning and conducting Investigation	T	T	S	S	S
Preparing material	T	T	T (as need)	S	S
Discovering scientific knowledge	T	S	S	S	S

Note: Adapted from Bell (2002: 15)

Source: Tofaya *et al.* (1980 cited in Bell, 2002), Colburn (2000) and DCID (2002)

According to Tofaya *et al.* (1980 cited in Bell, 2002: 16), the four types of inquiry include:

1) Confirmation activity: it is more teacher-directed. Guiding questions, step by step procedure, and materials are provided for learners. Learners engage in investigation in an attempt to rediscover explained phenomena.

2) Structured inquiry: it is less teacher-directed. Guiding question, steps of investigation, and materials are given to learners. However, learners conduct investigation in order to discover scientific knowledge they do not already know.

3) Guided inquiry: it is less teacher-directed. Guiding question and suggested material is offered. However, learners direct investigation and discover scientific knowledge.

4) Open inquiry: it is a leaner-centered. Learners generate question based on observations and interest. Materials are given as needed. Learners devise investigation and discover scientific knowledge. Teacher plays the role of facilitator of learning activity.

For Colburn (2000), learning cycle go beyond open inquiry. It happens when students apply the knowledge leant from activities into a different context. They then discover new concept and take ownership of the concept being discovered.

Teachers' Barriers for Implementing Inquiry-Based Instruction

Costenson and Lawson (1986) list ten of most common reasons that teachers do not incorporate inquiry into science classrooms. These include: 1) inquiry is time and energy consuming; 2) inquiry is too slow, especially when teachers have to cover the whole concepts in school curricula; 3) reading inquiry textbook is too difficult for students; 4) administrator do not understand when teacher use inquiry in class; 5) inquiry suits only with students who are formal thinkers; 6) students is not mature enough to do inquiry; 7) inquiry is not a part of teacher's teaching habit; 8) inquiry textbook requires teacher to follow its rigid sequence; 9) both teachers and students feel discomfort when using inquiry; and 10) teacher do not have appropriate materials for inquiry. Similar with the study of Costenson and Lawson (1986), Flick (1995) argues science teachers reject inquiry from their classroom because they believe the approach is time consuming; require appropriate materials; do not work with low ability and/or interest students, and require teachers' expertise and motivation. Bybee (2000) also reveals the reasons that science teachers often claim when they do not use inquiry. These reasons are consistent with the studies of Costenson and Lawson (1986) and Flick (1995). They are time consuming, costs too much, and too advance for students. In 2004, Roehrig (2004) studies 14 novice secondary science teachers regarding their constraints when attempting to teach science through inquiry. The five main constraints are: an understanding of the nature of science and scientific inquiry, content knowledge, pedagogical content knowledge, teaching beliefs, and concerns about management and students.

Anderson (1996 cited in Anderson 2002) clusters barriers and dilemmas science teachers face when teaching science through inquiry. He ends up with three dimensions: the technical dimension, the political dimension, and the cultural dimension. Anderson explains the teachers' barriers and dilemmas are from both external and internal factors. However, in his point of view, the internal one has most impact on teacher practice. Therefore, he thinks the cultural dimension would be the difficulty since it centers on beliefs and values of teachers in relation to students, teaching, and purposes of education. The details of each dimension are provided below.

1) The technical dimension includes limited ability to teach constructively, prior commitments (e.g. to a textbook), the challenges of assessment, difficulties of group work, the challenges of new teacher roles, the challenges of new student roles, and inadequate in-service education.

2) The political dimension includes limited in-service education (i.e., not sustained for a sufficient number of years), parental resistance, unresolved conflicts among teachers, lack of resources, and differing judgments about justice and fairness.

3) The cultural dimension involves the textbook issue, views of assessment and the "preparation ethic," i.e., an overriding commitment to "coverage" because of a perceived need to prepare students for the next level of schooling (Anderson, 1996 cited in Anderson, 2002: 8).

According to the literature, the confusion in the meaning of inquiry and inadequate or limited in-service education are the two of many crucial barriers that impede science teachers in implementing inquiry in science classroom. A number of scholars such as Bybee (2000), Anderson (2002), Roehrig and Luft (2004) and Wee *et al.* (2007) agree that before inquiry to be successful in helping students to accomplish science learning goals, teachers must first understand what inquiry is and then apply their understanding through the use of inquiry as a pedagogical tool. This notion is compliant with National Research Council (1996) in that it reveals teaching science through inquiry requires teachers to have not only content knowledge, skills to do inquiry, but also a profound understanding of what scientific inquiry is about.

One way for enriching teachers' knowledge and practice of inquiry in science classroom is to support them with professional development programs that provide the teachers with learning opportunities that are related to their actual classroom (National Research Council, 2000); that support collaboration with peers and experts (Blumenfeld *et al.*, 1994; Krajcik *et al.*, 1994; Anderson, 2002); and that enable them to reflect on their practices (Marx *et al.*, 1994). The following section provides a framework of inquiry-based instruction employed in this study as well as the process for establishing the framework.

Framework of Inquiry-Based Instruction Utilized in This Study

To promote the teachers' understanding and practice of inquiry-based instruction [IBI], there is a need for establishing a framework of science teaching through IBI. This framework is established with an attempt to guide the participating teachers in designing, implementing, observing, and reflecting on their own inquiry-based lessons. As Anderson (2002: 3) states, "inquiry means so many different things to different people, [thus] it is difficult for many people to visualize [inquiry] in actual practice" Thus, to understand inquiry, a number of scholars concur that it is important to identify various aspects of inquiry process and view them as a whole.

For setting up the framework of IBI, the researcher considers essential features of inquiry teaching and learning reported in the literature as well as American and Thai government documents. With regard to Thai documents, these essential features are derived from the goals of science teaching and learning, the role of teachers and students in science classroom, and the inquiry-oriented activities suggested by the NSCS (DCID, 2002: 3, 35-36), the 5Es inquiry process guided by the Manual of Science Teaching and Learning (DCID and IPST, 2002: 79-80). For the U.S. documents, the identification of scientific inquiry and the activities students do to learn science through inquiry stipulated in the NSES (NEC, 1996: 23) and the essential features of classroom inquiry provided by National Research Council (2000: 24-27) are incooperated.

Furthermore, in an effort for empowering the science teachers to take ownership of the professional development program, their current knowledge regarding IBI is credited. The teachers' prior perception of IBI is used as a structure for forming a complete picture of IBI. The framework of IBI utilized in this study is called "the essential features of IBI". (See how to involve the teachers' knwoledge about IBI into "the essential features of IBI" in the first central meeting in Chapter III). The essential features of IBI comprise of four aspects involving: 1) role of the teacher, 2) role of the student, 3) instructional objective, and 4) instructional process. Each aspect composes of essential features under it. All essential features of IBI are shown in Table 4.1 in Chapter IV.

As mentioned early, the aims of the study are to explore the three case study teachers' understanding and practice regarding IBI before and after they participated in the professional development program, the CAR Program. Therefore, the following section provides descriptions of action research, collaborative action research, and guiding principles underpinning the CAR Program.

Action Research: A New Approach for Professional Development

Historical Perspective of Action Research

Action research is firstly undertaken in the field of education in the mid 1950s by Corey. For Corey (1953), he believes teachers could change and refine their curriculum practice by researching on their own action. Teachers could be able to make better decisions regarding issues happened in their classroom. However, Corey is not the first person who proposes the process of action research. Yet, Lewin is the one (McKerman, 1991; Noffke, 1995; McNiff and Whitehead, 2002). Lewin's action research process composes of spiral steps. Each step includes a cycle of planning, executing (or action) and fact-finding (or reconnaissance) (Lewin, 1946). This process is later known as an action-reflection cycle of planning, acting, observing, and reflecting (Zuber-Skerritt, 1991; McNiff and Whitehead, 2002).

Back to Corey, his process of action research draws on Lewin's process. Corey's action research process also emphasizes a spiral of cycles which each cycle of research affecting subsequent ones. However, his process of action research different from Lewin's process in that it stresses on hypothesis-testing and involving of stakeholders in action research. Corey (1953) suggests that an action research study should involve all people who present a shared concern of topic being studied or those who are affected by the study. He refers to his action research study as "cooperative action research."

In 1960s and 1970s, action research is declined in U.S. However, it emerges and spread out in U.K. and Australia. For the U.K., Stenhouse is recognized as one of the most influential person on the movement of action research (Cochran-Smith and Lytle, 1992). His work is centered on teacher as researcher. He views teaching and research is closely connected. He believes teacher is the best judge of their own practice (McNiff and Whitehead, 2002). Stenhouse's notion of action research is further extended in the Ford Teaching Project which is viewed as a significant teacher-researcher development project that helps teachers to develop inquiry learning in their classrooms; and set up the distribution work of the Collaborative Action Research Network [CARN] (Kemmis and McTaggart, 1988). In Australia, the work of Kemmis and McTaggart articulate a version of action research in which teachers are involved in the project of human emancipation (Carr and Kemmis, 1986; Kemmis and McTaggart, 1988). Carr and Kemmis' process of action research involve a self-reflective spiral of planning, acting, observing, reflecting, and re-planning as the basis for understanding how to take action to improve an educational situation (Kemmis and McTaggart, 1988).

During the part 60 years, action research has been adopted, rejected, modified, and revised to meet the needs of the educational community. However, since the past 20 years action research in education has gained increasing attention. It is considerably as a practical but systematic research that enables teachers to investigate their own teaching and their students' learning. The process of action research conceptualized by Lewin (1952) is further adopted and developed by a number of educator, such as Corey (1953), Stenhouse (1975), and Carr and Kemmis (1986). However, the essence of action research stays the same. It involves the spiral of action-reflection cycle in which each cycle composes of four phases: plan, act, observe, and reflect.

General Description of Action Research

Action research has been defined by many scholars (e.g., Carr and Kemmis, 1986; Kemmis and McTaggart, 1988; Elliott 1991; McNiff and Whitehead, 2002; Stringer, 2007). Like scientific inquiry, action research refers to different things for different people and a generally accepted definition is undercover. A simple definition, but the most visualization in practice may be the one provided by Elliott (1991), "a study of social situation that aims to improve quality of action within it". In this regard, action research is viewed as a way that helps people to change their action within a particular context. McNiff and Whitehead (2002: 15) view action research as a way of "researching your own learning". Similarly, Stringer (2007: 1) clarifies "action research is a systematic approach to investigation that enables people to find effective solutions to problems they confront in their everyday lives". Action research, in this sense, is conducted by people who want to research on their own problems. They intend to change and understand their action regarding the problems being investigated. Another clear and well accepted definition is stated by Kemmis and McTaggart (1988: 5),

> Action research is a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or education practices, as well as their understanding of these practices and the situation in which these practices are carried out.

For Kemmis and McTaggart (1988), collaboration is a basic element of action research. The action research study must be conducted by a group of people who have shared concerns about a topic being researched. The group members must plan action and reflect on their practice together. However, they may act and observe their action as individuals.

Whatever the term refers to, whether the definition presents a concrete or an abstract mean, and whether the research is carried out by each individual or group of practitioners, the aim of action research is clearly stated. Action research aims to improve practice, to better understand the practitioners' own practice, and to make change of the situations in which that practice takes place (Carr and Kemmis, 1986; Kemmis and McTaggart, 1988; Zuber-Skerritt, 1991). Therefore, the study focuses on a particular problem of practitioners rather than a global issue in education.

Fundamental Features of Action Research

Several key characteristics of action research have been discussed on the literature (Zuber-Skerritt, 1991; McNiff, Lomax, and Whitehead, 1996; Kemmis and McTaggart, 2000; Christensen, 2005). These features are: practitioner research, focus on practice, self-reflection, democratic leadership, professional development, link theory into action, recurrence of action-refection cycle, and collaboration. The detail of each feature is provided below.

1) Practitioner Research: Action research is a practitioner research which means the research is conducted by individuals into their own practice (McNiff *et al.*, 1996). Topics being investigated center on practitioner's practical problems and concerns (Zuber-Skerritt, 1991) rather than global issue. Action research enables

practitioners to explore their experience, to have a better understanding of their practice, and to apply that knowledge to solution of focused problems (Zuber-Skerritt, 1991). Researcher who carries out an action research is viewed as a colleague doing the research with and for practitioners rather than doing an inquiry with subject.

2) Focus on Practice: One of the major aims of action research is to improve practitioners' practice regarding immediate problems. Therefore, the practitioners' action is considered as the main focus of action research process. For Elloitt (1991), action research is an inquiry of practioner who wants to improve his/her own practice. Action research helps to release practitioners from the constraints (e.g., unproductive, unjust, and unsatisfying social structures) that limit their self-development and self-determination (Kemmis and McTaggart, 2000).

3) Self-Reflection: One of the key characteristic of action research is self-reflection. In action research, practitioners learn to improve their practice by reflect on their action. They link what they learn from reflection to new practice (Kemmis and McTaggart, 1988; Winter, 1996). In doing so, the practitioners are self-reflection and self-evaluation on their own inquiry (Collins, 2004).

4) Democratic Leadership: All people who are involved in an action research are concerned as equal "participants" contributing to the inquiry (Zuber-Skerritt, 1991). No hierarchy is presented in the action research process. A group of people solve problems together in a creative and productive way. They are equity in terms of trying out ideas, presenting their learning, making decision on their own practice, and probably controlling the research process and findings.

5) Professional Development: Action research provides a crucial connection between self-evaluation and professional development by involving reflection among practitioners (Winter, 1996). By reflecting their action with each other, the practitioners gain a grater understanding of their practice and that understanding results in new action. In doing so, action research involves self-developing through inquiring into our own practice. McNiff *et al.* view (1996) action research as insider

research and they believe when conducting action research, all researchers engage in a form of professional development.

6) Link Theory into Practice: Action research process provides a link between theory and practice into a single product, called "ideas in action" (Kemmis and McTaggart, 1988; Winter, 1996). Action research is considered to respond to the growing need for more relevant and practical knowledge in the social sciences (de Zeeuw, 2003). Through the action research process, the practitioners are invited to try out ideas in their practice in order to improve and increase their knowledge (Kemmis and McTaggart, 1988). In this regard, action research helps to bridge a gap between academic research and day-to-day practice. In other words, action research is a research that brings theory into practice.

7) Repetition of Action-Reflection Cycle: In terms of method, a spiral of cycles of planning, acting, observing and reflecting is central to the action research process (Carr and Kemmis, 1986). Practitioners engage in an action-reflection cycle several times in order to create change in their practice.

8) Collaboration: The term "collaboration" is problematic in action research. A number of scholars claim collaboration is a key characteristic of action research (Lewin, 1946; Carr and Kemmis, 1986; Kemmis and McTaggart, 1988; Elliott, 1991). In collaboration, participants of action research project "set common goals, plan the project, collect and analyze data, and report the results" (Christensen, 2005). However, the degree of collaboration can be varied, depending on the involvement of practitioners in the research project. Nevertheless, several scholars argue collaboration is not a key aspect in action research since some types of action research (e.g., classroom action research, self-study) can be done as individuals.

According to the current study, collaboration is considered as a basic element of action research because the study involves a group of teachers to engage in the professional development program that encourages them to plan, act, observe, and reflect on their action. The teachers had shared concern. They learned to improve their understanding and practice by reflecting and sharing ideas with each other.

Action Research Process

For the current study, the process of action research developed by Carr and Kemmis (1986) and Kemmis and McTaggert (1998) is adopted. This process consists of four phases: plan, act, observe, and reflect. As Kemmis and McTaggart (1988: 10) clarify,

> To do action research, a group and its members undertake a) to develop a plan of critically informed action to improve what is already happening; b) to act to implement the plan; c) to observe the effects of the critically informed action in the context in which it occurs, and d) to reflect on these effects as a basis for further planning, subsequent critically informed action research and so on, through a succession of cycles.

In this regard, group members must carry out the four activities collaboratively. The group members has shared goal. By following the action-reflection cycle, it leads to the identification of a new problem and therefore, a new cycle of planning, acting, observing, and reflecting. The action-reflection cycle is replicated, and ultimately forms the action-reflection spiral, as display in Figure 2.1.

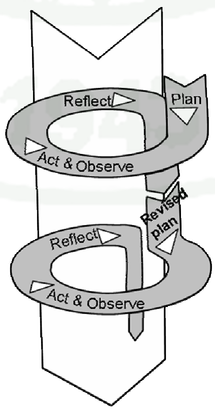

Figure 2.1 Action-Reflection Spiral

Source: Adapted from Kemmis and McTaggart (1988: 11)

Zuber-Skerritt (1991) clarifies that these four phases of action-reflection cuycle are drew upon a fundamental assumption that people can learn and create knowledge by experiencing; observing and reflecting on that experience; forming abstract concepts and generalizations; and testing the implication of these concepts in new situations.

Collaborative Action Research: A Form of Action Research Employed in the Study

The form of action research that frames this study is collaborative action research. Oja and Smulyan (1989) argues collaborative action research is a form of action research which brings together teachers, staff developers, and university researchers with the goals of improving practice, contributing to educational theory, and providing staff development. This form of action research demands that research is practitioner-based, and that all theorizing and practice takes place in the practitioners' setting (e.g., schools, classrooms) (Collins, 2004). The research is carried out in teams. Each team negotiates a group project which addresses its members' concerns. They then follow the action-reflection cycle in conducting its project. However, the projects themselves are documented and analyzed by researcher who looks for insights into the process of effective action research (Christensen, 2005).

Oja and Smulyan (1989) outline four basic elements of collaborative action research. These include collaboration in nature, support open communication, focuses on practical problems, and emphasizes professional development. Collaboration is a key characteristic of collaborative action research in that it allows mutual understanding and consensus, democratic decision making, and common action among collaborative action research project's members (Kemmis and McTaggart, 1988; Christensen, 2005). Collaborative action research also encourages open communication. The practitioners' voices are acknowledged and valued as an integral part of collaborative action research projects. Like other kinds of action research, collaborative action research focuses on practitioners' immediate problems. By engaging in collaborative action research, the practitioners gain new knowledge which helps them solve their problems, broaden their knowledge-based as professionals, and learn research skills which can be applied to future interests and concerns (Street, 1986). The practitioners become more flexible in their thinking, more receptive in new ideas, and more able to solve problems as they arise, so that their professions are grown. Oja and Smulyan (1989) argue the efficacy of collaborative action research project is depended on the project structure which allows these basic elements to emerge. They suggest four methods for fostering the project efficacy including: frequent and open communication among practitioners; democratic project leadership; recurring of action-reflection cycle; and positive relationships with the context within which the project is carried out.

Guiding Principles of the Collaborative Action Research Program

The professional development program, known as collaborative action research program [CAR Program], conducted in this study is guided by the fundamental features of action research (Kemmis and McTaggart, 1988, 2000; Zuber-Skerritt, 1991) and collaborative action research (Oja and Smulyan, 1989). These are: a) focus on practice, b) emphasis on professional development, c) self-reflection, d) democratic project leadership, e) time and support for opening the communication, f) collaboration, and g) recurrence of action-reflection cycle. The CAR Program is also designed to meet the desirable features of teacher professional development program in Thailand which include: a) having long-term support for teachers both in groups and as individuals, b) conducting in teachers' actual classroom, c) encouraging teachers to change their practice, d) being part of the teachers' regular duties, e) promoting collaboration between teachers and program facilitator, f) empowering teachers' sense of ownership, g) requiring teachers' willingness, h) working in a friendly atmosphere (Office of the Education Council, 2004; Puntumasen, 2004).

Relevant Studies

Collaborative Action Research in Changing Science Teacher's Understanding and Practice

Krajcik *et al.* (1994) provided a description of their collaborative work on project-based instruction with middle schools teachers. During this collaborative program, science teachers worked collaboratively with colleages, university personnel, and experts regarding science content and technology. They planned and enacted several project-based instructions, reflected on their experiences, and returned to the group to share experiences and strategies for sloving difficulties, as well as supporting each other. The study reported that by engaging in the cycles of collaboration, enactment, and reflection, teachers and university personnels perceived new visions of project-based instruction, developed rich conceptions of the features and associated challenges of project-based instruction, and learned strategies for enacting practices that was aligned with theory.

Feldmann (1996) reported his study with a group of eight physics teachers who engaged in a 3-year collaborative action research project. The study aimed to examine the ways that the teachers came to change their knowledge about teaching and their educational situations while they participated in the project. The data were gathered from multiple sources including teachers' interviews, classroom observations, collaborative action research meetings and teachers' writing. The data were analyzed through the development of grounded theory to construct coding categories. The findings indicated three mechanisms that the teachers used for generating and sharing knowledge and understanding regarding their practices: anecdote telling, trying out of ideas, and systematic inquiry. The study also reported that the teachers' knowledge and understanding were enriched by connecting the activities in the project with teachers' real lives in schools and the teachers' normal practice.

Briscoe and Peters (1997) investigated how collaboration between teachers from several schools and university researchers facilitated elementary teachers to change their practices. The collaboration was built into an in-service project for elementary teachers. The project aimed to assist the teachers in implementing science curriculm that was centered on problem-based learning. Twenty-four elelmentary teachers were involved in a 3-week summer workshop and an intensive follow-up program in the follwong school semester. The data were obtained from multiple sources including interviews, group meetings, lesson plans, teachers' produced artifacts, and field notes from classroom observations. The finding revealed that collaboration supported the change among the elementary teachers since it provided opportunities for the teachers to learn scientific knowledge and pedagogical content knowledge from each other. It also encouraged the teachers to be risk takers in implementing new ideas, and supported as well as sustained the processes of change of individuals in science teaching.

Balach and Szymanski (2003) documented the growth of the group as a professional learning community. The group included preservice and in-service teachers, an administrator, and a university professor who planned and implemented a collaborative action research study in a suburban middle school. Data were collected from pre- and post-test surveys and examination of participants' ongoing reflections and personal stories. Results revealed that the group made notable advances in the development of dialogic skills, a shared understanding of how teachers must lead a life of mind, and awareness of methods to crate a context that supported change.

The study of Christensen (2005) documented a 38 week collaborative action research project conducted by two experienced high school science teachers who investigated their own practice in an effort to enhance their students' engagement in the process of scientific inquiry through laboratoty activities. The study aimed to exmine how the teachers understood their practice. The study revealed that the teachers learned to understand their practice by engagaing in the research and constructing their own understading of research. It also reported that collaborative action research was a viable way to change teacher's practice.

Naylor (2007) explored the concepts, contexts, and directions of collaborative teacher inquiry as a form of professional development for teachers in British Columbia's K-12 public schools. The data were obtained from six inquiry projects conducted between 1992 and 2006. The study showed that collaborative teacher inquiry demonstrated value to teachers who participated in it as a professional development. This value included a sense of professional efficacy, reduction of isolation, and the belief of benefit of the teachers' inquiry to students. The study also suggested that those who did the inquiry needed to understand contexts in which the inquiry took places.

CHAPTER III

RESEARCH METHODOLOGY

Introduction

The purpose of this study was to assess any changes of science teachers' understandings and practices of inquiry-based instruction [IBI]; therefore, qualitative methods for gathering and analyzing the data were employed. In this chapter, there are four sections. The first section describes qualitative research, interpretive paradigm, case study method, as well as the rationales. Subsequently, the second section provides context of the study including research sites, participants, and the collaborative action research program [CAR Program]. Then, the third section describes data collection methods and data analytical procedures. Finally, the last section addresses all techniques utilized in this study to ensure its trustworthiness.

Methodological Framework

Qualitative Research

All research is framed by fundamental beliefs of what researchers perceive as reality, knowledge, and way for studying the world (Patton, 2001). These beliefs guide researchers to methods and strategies appropriate for studying social phenomena (e.g., a group, event, program, community, or interaction) (Merriam, 1998). For the current study, it is framed by qualitative research. The primary aim of qualitative research is to study social phenomena in real-world setting (Patton, 2001). There is no endeavor of the researchers to manipulate the phenomenon they investigated. Conversely, the researchers study the phenomenon as it unfolds. They do not have determination of what the outcome is. Rather, the researchers allow the outcome to come out from the data. The qualitative approach of inquiry contrasts with quantitative studies in many ways. As Patton (2001) gives an example, in experimental design, quantitative researchers control context surrounding variables beging studied. They minimize all external variables that could influence their interested variables and then measure only the variables of interest. The researchers also predict the outcome of the study in advance.

In educational field, there are some educators who characterize the fundamental characteristics of qualitative research (Merriam, 1998; Rossman and Rallis, 2003). According to Merriam (1998), five fundamental features of qualitative inquiry are significant. Firstly, qualitative research focuses on the interpretation and meaning that people have constructed from what they sense or experience from the world. Secondly, qualitative researcher is the instrument for data collection and analysis. The researcher interviews subjects, observes their behaviors, and collects documents such as lesson plans, diaries, journals, or student work. The researcher looks for categories, themes, or patterns that appear from these data. Thirdly, qualitative research usually involves with fieldwork. The researcher interviews, observes, and collects the data while subjects are performing tasks in an ordinary working area or situation. Fourthly, the research fundamentally employs inductive analysis. Hence, the researcher does not establish the outcome, hypothesis, or theories beforehand. Rather, the researcher seeks out patterns or themes that emerge from the data. Finally, the researcher reports the finding of the study in rich and full description. Qualitative researchers describe the context of the study, participants, and interested activities through their own words and support their findings with direct citations from documents and excerpts from interview or videotape data.

Interpretive Methodology

Qualitative research is an umbrella approach that covers various methodologies or forms of inquiry (Merriam, 1998; Marshall and Rossman, 2006). The current study is framed by a methodology align with qualitative inquiry. This methodology is known as interpretive methodology (Marshall and Rossman, 2006). Interpretive methodology is based on the assumption that reality is broad and subjective. It is individually and socially constructed (McMillan and Schumacher, 1997). The meaning is derived from one’s experience and his/her context. Therefore, to access reality, interpretivist researchers must study people in their contexts (Lincoln and Guba, 1985). The researchers must immerse themselves in the field where the participants are involved and attempt to uncover and understand how the participants construct meanings of the social phenomena. In short, the researchers must view the world through the lens of their participants. The aim of interpretive studies in general is to understand how people interpret the social world, construct meanings, and interact with the social nature in a particular context. Interpretivist researchers are likely to utilize qualitative methods to deal with multiple realities (Lincoln and Guba, 1985). The researchers must prepare themselves in the field in which the participants are involved. With this regard, the researchers themselves are data-gathering instruments (Lincoln and Guba, 1985). They conduct interviews, observe people's actions, and gather available documents. Qualitative methods enable interpretivist researchers to broaden their views into the way participants perceive the world and reveal its meaning.

In the field of science education, interpretive methodology is commonly used with an effort to understand teachers and students regarding the ways they make sense of and give meaning to the social interactions that are bounded within the school context (Gallagher and Tobin, 1991). In the case of this study, the researcher begins the study with an assumption that the participating teachers do have prior perception regarding IBI. The researcher also believes the teachers hold existing experience of how to implement inquiry-based approach in their classrooms. The challenge is to track and uncover what the teachers know about and how they practice IBI before and after they participate in a professional development program. In this study, the researcher neither controls nor manipulates the participants and their environments. Rather, the researcher studies the teachers in a natural setting. The data are gathered from interviews, observations, and documents. They are then analyzed by being interpreted to seek for patterns or themes. Therefore, the study is framed by qualitative research and interpretive methodology.

Method of the Study

The method of the study employed in this particular research is qualitative case study. Qualitative case study method is a research strategy widely utilized in education (Merriam, 1998). The purpose for implementing qualitative case study method is to gather comprehensive, systematic, and in-depth information about individual cases (Patton, 2001). According to Stake (2005), case study is the study of the individuality and complexity of a single case (or cases) in which researchers come to understand the activity of a case (or cases) within its circumstances. Stake (2000) argues anything can be defined as a case, particularly, if it (the object of study) is a specific, unique, and bounded system. According to Yin (2002), the case study method is relies on multiple sources of data (e.g., interviews, observations, documents, or artifacts), and these data need to be converged in a triangulation. Once the case data is analyzed, the findings are reported via "thick description" (Merriam, 1998). Thick description helps the readers to understand results of a case more clearly than presenting the findings with abstract theories or principles.

As mention previously, the aim of this study is to examine the changes of individual teachers' understanding and practice of IBI before and after they were involved in a professional development program, known as the CAR Program. Therefore, the qualitative case study method is in agreement with the aim of the study because the method enables the researcher to gather comprehensive and in-depth information of individual teachers. Furthermore, the characteristics of qualitative case study method are compliant with the researcher's philosophical beliefs on reality, knowledge, and methods for reaching knowledge. In the particular study, a case refers to a lower secondary science teacher who volunteers to join in the CAR Program; hence, the study consists of three cases of three teachers.

Context of the Study

This section provides background information including the research sites where the study was conducted, characterization of the science teachers who volunteered to participate in this study, and a description of the processes for initiating and establishing the CAR Program.

Research Sites

This study was conducted in two lower secondary schools governed by the Department of Education Bangkok Metropolitan Administration [BMA], Bangkok, Thailand. They were 2 of 58 schools that participated in the Project for Extension Opportunity at Lower Secondary Level (also known as the EOLS Project) as described in the Chapter II. These two schools were located in suburban areas of Bangkok Metropolitan, nearby Kasetsart University. The schools had two semesters per year; the first semester ran from May to September and the second semester ran from November to March. There were two school breaks in each academic year; the first school break was in October and the second one was in April.

This study was conducted at Thai Authid School[1] and Pracha-niyom School. These schools enrolled the students from kindergarten to grade ninth level. However, the study focused only on science teachers who taught at lower secondary level which involved students in the 7^{th}–9^{th} grades. The detailed information regarding the two schools is described below.

Thai Authid School was a public lower secondary school located in Don Muang district. This school was situated in a suburban area surrounded with the lower- and middle-class family houses, townhouses, apartments, a construction material and hardware store, and a nightclub. The school was established in 1975. To date, this school had 7 school buildings, one out-door sport field, a science laboratory room, an electric laboratory room, a botanical garden, a green house, and a library. The school also had received tremendous support from the BMA for scientific materials and equipments. In 2008, the number of students attending in this school was approximately 2,700. There were around 250 students in the lower secondary level: 3 classes of grade seven, 2 classes of grade eighth and 2 classes of grade ninth.

[1] Pseudonyms are being used for the schools and the participants.

The class sizes ranged between 30 and 35 students. In 2008, Thai Authid School hired 115 government teachers under the support of the BMA.

Pracha-niyom School was also a public lower secondary school and it was located in Bangkhen district. The school was situated in a suburban area surrounded with middle class housing, townhouses, police station, the Department of Military Communication, the office of Bangkhen District, and two shopping malls. It was established in 1941. The school had 9 school buildings, a sports field, a library, a swimming pool, a cultural centre, and a number of small size gardens. Unlike Thai Authid School, this school did not have a science laboratory room for the 7th–9th grade students. Furthermore, the scientific materials and equipments for science instructions in this school were usually insufficient. In the 2008 academic year, the student enrollment of this school was approximately 3,300. There were 850 students in the lower secondary level, with 8 classes of the grade seven students, 6 classes of grade eight students, and 5 classes of grade nine students. The class sizes ranged between 40 and 45 students. In 2008, this school had 137 government teachers under the support of the BMA.

In both schools, students came from lower or middle class families. Their parents were workers, merchants, or agriculturists. Most students did not live in the vicinity of the school communities. Rather, they followed their parents or relatives who migrated from other cities or provinces to Bangkok for their works. With respect to teaching and learning science, the lower secondary level students in both schools learned science 3 periods a week (one hour/period). They therefore studied science 120 hours a year. In the 2008 academic year, science subjects in both schools were taught based on the National Science Curriculum Standards [NSCS] (DCID, 2002).

Participants

Since generalization is not the major goal of the qualitative case study method, the most common strategy used for selection of the sample is purposeful sampling. This sampling method is based on the assumption that the researcher wishes to learn and gain profound understanding of the subjects who are being investigated (Patton, 2001). Three science teachers from two different schools were purposefully selected for this study. All of them taught science subjects in the lower secondary level of the schools engaged in the EOLS Project. To recruit the participants in this study, questionnaires were mailed to individual science teachers in every lower secondary schools participating in the EOLS Project (Ketsing and Roadrangka, 2008). The last section of the questionnaires contained a brief description about this research and a question that asked the teacher to indicate if he/she wished to participate in the study and to provide the reason(s) that they wanted to participate. There were 34 questionnaires returned (58.6%) to the researcher. Twelve teachers (35.3%) indicated their interests and willingness to join in the study. Seven of 12 teachers were chosen based on the three criteria of selection. First, they were willing to engage in the study because they wanted to improve their instructional practice of IBI. Second, the teachers had never attended any professional development programs or workshops on IBI during the past three years (2004-2006). Last, schools of these teachers were located nearby Kasetsart University. It was a requirement for the participants that they were able to attend all meetings organized at the Faculty of Education, Kasetsart University while engaging in the CAR program. Subsequently, the researcher visited the individual teachers in their schools and had a conversation with the school administrators regarding the study plan. Initially, Mr. Phichit, Mr. Suriya, and Miss. Manthana were three science teachers from the different schools who volunteered to participate in the current study. However, Miss. Manthana had to resign from this study early because she was assigned by her school administrator to engage in another project. Concurrently, Phichit had invited his colleague, Mr. Monsid, to join this study. After checking Monsid’s information to determine whether it met the three criteria above, the researcher accepted his application. The study started in July, 2008 and finished in February, 2009. The general background of these participants is provided in what follows.

Case I: Mr. Phichit

Phichit was an in-service science teacher at Thai Authid School. He was 29 years old and has six years experience in science teaching at a public school governed by the BMA. For the educational background, Phichit received a Bachelor's degree in Science (Applied Biology) and a graduate diploma in Teaching Profession from Rajchapat University. He gained a scholarship from the Project for Preparation of Talented Science and Mathematic Teachers [PTSM] for studying in bachelor degree and diploma. Thus, he was able to become a government teacher without a meeting the requirement of passing the government examination for teaching license. Phichit started his teaching career at Thai Authid School and had taught science since 2002. In 2007, he received a Master's degree in Science Education from a government university. During the period of this study, he was teaching several subjects including science, basic vocation, scouting, and counseling for the 7th grade and 8th grade students. His science classes had approximately 35 students. Besides his teaching responsibility, he was the head of the Science Department and a staff member of the administrative section and the audiovisual section in his school.

Case II: Mr. Monsid

Monsid was a 32-year-old in-service science teacher at Thai Authid School. He had 10 years of the experience in science teaching at both the private and public schools in Bangkok. He received a Bachelor's degree in Education (Chemistry) from the Institute for Teacher Preparation in Bangkok. Then, he started his career as a teacher in a secondary private school in Bangkok. He taught chemistry for one and a half years, and then he passed the BMA examination for teaching license. In 1999, Monsid was hired by the BMA at Thai Authid School. During the period of this study, he was assigned to teach the 9th graders several subjects including science, vocation, agriculture, scout, and counseling subjects. In the science classroom, there were approximately 35 students. Phichit was also a homeroom teacher for the 9th grade class.

Case III: Mr. Suriya

Suriya was a 51-year old in-service science teacher in Pracha-niyom School. He had 32 years of teaching experience in a public elementary school and lower secondary school in Bangkok and had been teaching science for 10 years. He received a Bachelor's degree in Physics Education and a Master's degree in Adult Education from the Institute for Teacher Preparation in Bangkok. After Suriya had completed his undergraduate study, he passed the BMA examination for teaching license and started his teaching career in an elementary school. Suriya taught English language in elementary level for 20 years. After receiving a Master's degree in 1997, he decided to be a teacher at Pracha-niyom School. At that time, the school had just established the lower secondary level. Since then, he had been teaching science for 7^{th}–9^{th} grades. In the academic year 2008, he taught science, elective subjects, and scouting in the 9^{th} grade. There were around 40 students in his science class. Instead of teaching, Suriya was a homeroom teacher of a 9^{th} grade class. In addition to his teaching he also worked for the administrative section, students' activity section, and audiovisual section in his school.

Collaborative Action Research Program

The collaborative action research program [CAR Program] is a professional development program established in this study. It aims to enrich lower secondary level science teachers' understanding and practice of IBI in their own classrooms. The program was designed based on a number of principles consistent with the desirable features of teachers' professional development program in Thailand. These features include: a) having long-term support for teachers both in groups and as individuals, b) conducting in teachers' actual classroom, c) encouraging teachers to change their practice, d) being part of the teachers' normal practices, e) promoting collaboration between teachers and the program facilitator, f) empowering teachers' sense of ownership, g) requiring teachers' willingness, and h) working in a friendly atmosphere (Puntumasen, 2004; OEC, 2004). The CAR Program was also developed according to fundamental characteristics of action research (Kemmis and McTaggart, 1988; Zuber-Skerritt, 1991; Kemmis and McTaggart, 2000) and collaborative action research (Oja and Smulyan, 1989), which included: a) focus on practice, b) emphasis on professional development, c) self-reflection, d) democratic project leadership, e) time and support for opening the communication, f) collaboration, and g) recurrence of action-reflection cycle. The following section provides the descriptions of the goals, the program members, the roles and expectations of the members, and the program's procedures.

Goals of the CAR Program

The CAR Program was designed for accomplishing two ultimate goals: 1) to promote science teachers' understanding of IBI and 2) to enrich the teachers' practice of IBI in their actual classrooms. Throughout the CAR Program, the three science teachers learn to improve their knowledge and the use of IBI via the repetition of action-reflection cycle and the meetings of the collaborative action research team.

CAR Team

There were five persons who were involved in the CAR Program. These people were called the collaborative action research team [CAR Team]. The CAR Team comprised of three science teachers who taught at lower-secondary level, one researcher, and one science educator. The team members had a shared goal. Their goal in common was to promote the science teachers' understanding and practice of IBI in their real classrooms. The CAR Team met often throughout the CAR Program. The meetings were held at both the central meeting site (the Faculty of Education) and at each teacher's school. The meetings that occurred at the central meeting site were labeled as "central meetings" while the meetings that happened at the teachers' schools were called "one-to-one meetings". Hence, the "CAR Team" term used in this study referred to not only when all members of the team met at the central meetings, but also when individual teachers worked with the researcher in the one-to-one meetings.

Role of CAR Team Members

Role of the Researcher

The researcher's role on the CAR team was that of the teacher's assist. As an assistantance, the researcher was to facilitate and assist each teacher in their learning of IBI through the work in the action-reflection cycle and the meetings of the CAR Team. For one-to-one meetings, the researcher assisted the teachers regarding the production of an inquiry-based lesson plan, the implementation of the lesson, and the points of IBI when they confronted difficulties or confusions in understanding and practice. The researcher facilitated the teachers by video-recording their inquiry-based teachings and giving the videos to the teachers to observe and reflect on regarding their instruction. For the central meetings, the researcher organized the activities that helped to promote the teachers' knowledge and their use of IBI in their classrooms. The researcher also provided the teachers with useful references regarding IBI.

The researcher interviewed each teacher several times throughout the study process. She collected the teachers' inquiry-based lesson plans and written reflections. The researcher monitored and videotaped the teachers' implementations of inquiry-based lessons and discussed these events with the CAR Team at the central meetings. During the monitoring, the researcher was a non-participant observer.

Role of the Teachers

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

Role of the Science Educator

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

CAR Team Meetings

With respect to all of the CAR Team meetings, there were four meetings that occurred at central meeting site (also referred to as central meetings). The rest of the meetings were held at individual teachers' schools (referred to as one-to-one meetings). The major aims of the central meetings included: 1) to provide the science teachers with the opportunity to share their inquiry-based lesson plans, teaching experience, and difficulties in understanding and implementing the lessons; 2) to assist and support each other in improving inquiry-based lessons; and 3) to learn

IBI through reflection on their own instruction, communication with each other, and participation in activities provided in the meetings. For one-to-one meetings, the primary aims of the meetings were to facilitate individual teachers to work through the action-reflection cycle and to assist them regarding the points that they found difficulties in understanding and practice. All meetings that occurred in this study were video- or audio-recorded. The four central meetings were held in a medium size lab classroom in the Faculty of Education, Kasetsart University. The one-to-one meetings commonly occurred in the teachers' science classrooms or offices. More detail of the meetings is provided in the section below. The schedule of overall meetings and topics discussed in one-to-one meetings are shown in Appendix C.

CAR Program Procedure

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

Phase 1: Preparation

The Preparation phase took place from July to October, 2008. This phase started at the beginning of the first semester launching from July to September and was completed by the first school break in October. In July 2008, after the school administers and participants agreed to be involved in the study, the researcher sent consent letters to the Dean of the Department of Education, Kasetsart University for approval. After being approved, the consent letters were sent to the school administrators and then to the participants. At the beginning of July, the researcher met each teacher at the school in order to set up the common goal of the CAR Program, to consult with teachers regarding the program procedure, and to inform the teacher about their role and obligation as a member of the CAR Program and a research participant. The researcher also visited the teachers at their schools regularly. These school/classroom visits aimed to build familiarity, trust, and a respectful atmosphere among the researcher and teachers, as well as to familiarize the researcher with the teachers' teaching contexts. In addition, it provided opportunities for the teachers to practice their written reflection on their teaching. During these visits, the researcher observed the teachers' classrooms and talked informally to the teachers about several issues such as science teaching and learning, students' background, school, teachers' obligation, and teachers' background. To provide practice with writing of reflections, the teachers were given a reflective protocol to guide their writings. The researcher then provided feedback on their writing. The reflective protocol is shown in Appendix A. The schedule of the school/classroom visits is displayed in Appendix C.

In August 2008, the researcher began to assess what the teachers knew about, and how they practiced IBI before they participated in the professional development experience from the CAR Program. In the middle of this month, the case study teachers were interviewed individually regarding science teaching experience, prior understanding of IBI, and their reasons and expectations for participating in the CAR Program. The interviewing process is described in the section of data collection. The interview protocol is shown in Appendix B. To augment the interview data, individual teachers were asked to design and implement three inquiry-based lessons according to their prior knowledge. The teacher taught the lessons in their actual classrooms in August and September 2008. For Thai context, it is expected that developing a lesson plan is an essential and regular part of the teacher's practice. Thai teachers are expected to write their lesson plans before they implement the lessons. For the current study, the teachers' inquiry-based lesson implementations were observed and video-recorded. In observing these lessons, the researcher played the role of a non-participant observer. After completing each lesson, individual teachers were given a DVD of their instruction. The DVD allowed the teachers to observe their own instruction and reflect on their practices. During this phase, the researcher did not provide guidance for the teachers regarding IBI. She only offered suggestions on how to reflect on their practices. During this period, the data was obtained from interviews, classroom observations, teacher's inquiry-based lesson plans, and teacher's written reflections.

The Preparation phase was completed with a full day meeting during the first school break in October 2008. The Thai teachers had no teaching responsibilities in this period of time; therefore, they had some 'spare' time for attending the meeting. Details of the first central meeting are provided below.

First Central Meeting

The first central meeting aimed: 1) to encourage the teachers' awareness of the importance of IBI in science; 2) to set up the essential features of IBI of this study; 3) to provide the teachers with the opportunity to share their first lesson plan, teaching experience, and difficulties in understanding and implementing an inquiry-based lesson; 4) to assist and support each other in improving inquiry-based lessons; and 5) to learn IBI through reflection on their own instruction, communication with each other, and participation in activities designed by the researcher. At the beginning of the meeting, the researcher formally introduced herself and all members to each other. She then informed the common goal of all members for engaging in the CAR Program. After that, the researcher described the roles of the CAR Team's members which included the teacher role, the researcher role, and the science educator role. This was followed by an overview of the CAR Program, the objectives of the first central meeting, and the activities provided in the meeting, respectively. Afterward, the researcher introduced the teachers to the first, second, and third activities, sequentially. It should be noted that most of the activities provided in the central meetings were designed based on the principles of action research (Kemmis and McTaggart, 1988). In the activities, the teachers were provided the opportunity to build their knowledge and refine their practice of IBI by reflecting upon their practices and communicating with each other in the CAR Team. The teachers were involved in all activities in a supportive and friendly environment. A summary of these activities is provided below.

Activity I: Learning the Importance of IBI

Activity I was designed to intensify the participants' awareness of the significance of teaching and learning science through inquiry. At the beginning of the activity, the researcher explained the purpose of the activity. She then invited the teachers to share ideas regarding: "what do you think are the benefits of IBI in terms of students' learning?" After the discussion, the researcher provided a summary of the teachers' ideas. She then asked the teachers to analyze an excerpt gathered from the NSCS (DCID, 2000) and then share their thoughts with the CAR Team. The excerpt used in the activity was:

> In teaching and learning science, learners should understand that science is referred to both knowledge and process of inquiry. All learners should be enthusiastic in learning science. They should be curious and ask question regarding natural phenomena. Learners should be fascinated and happy in inquiring knowledge, collecting and analyzing data, and formulating answer of their question. They should be able to make decisions based on evidence. Ultimately, learners should be able to communicate their questions, data, and answers with others. (DCID, 2002: 3)

In sharing and discussing this passage, the researcher provided questions for guiding the teachers to some aspects of the essential features of IBI including the purpose of teaching science, the teacher role and the student role in inquiry-based classroom, and some crucial features of inquiry process such as "inquiry process should begin with students' interest and curiosity" and "inquiry process begins with question". The researcher also provided the NSCS documents for checking or reviewing of what the Standard expected science teachers to do and learners to learn. After the discussion, the researcher provided a summary of what the CAR Team had learned from the activity in relation to IBI. However, it was important to remember that at this point in time the teachers did not exactly know what the essential features of IBI in this study looked like. Therefore, the implicit purpose 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 features of IBI.

Activity II: Generating the Essential Features of IBI

The purposes of Activity II were: 1) to provide the teachers with a chance to share their teaching experience, reflection, and difficulties in understanding and teaching inquiry-based lesson; 2) to assist and support each other in improving inquiry-based lessons; 3) to learn IBI through reflection on their own instructions and communication with each other; 4) to establish the essential features of IBI. At the beginning of the activity, the researcher informed teachers of the purposes of the activity. She then invited individual teachers to share their inquiry-based lessons. The teachers presented their lessons by following a set of guiding topics the researcher provided. These topics included: classroom context, teaching and learning objective, instructional process, the teacher role, the student role, and issues of concern. In the activity, the teachers had freedom to select their favored lesson and method of presentation. The teachers chose to show their real lesson plans via Visualizer. The researcher helped the audience to understand the classroom context by showing pictures of the teachers' classrooms via LCD Projector. After the presentation of each teacher, there was an open floor for the CAR Team members to critique the inquiry-based lesson, provide suggestions, and support their peers' success. During this period, the researcher supported the discussion by raising questions in relation to the essential features of IBI. These questions aimed to enrich the teachers' perspectives regarding IBI. In addition, the teachers were encouraged to reflect on their lesson plans and instructions. The reflection focused on what the teachers viewed as essential features of IBI in their lessons.

After all three teachers presented and discussed their lessons, the researcher asked the teachers to compare and contrast their lessons in order to seek out the essence of inquiry teaching. The researcher then listed the features that the CAR Team members agreed were the crucial characteristics of inquiry teaching. As a member of the CAR Team, the researcher brought up some features that she believed were essential for classroom inquiry, and discussed these with the team members. After the discussion, the CAR Team members ultimately agreed on four aspects, which included: 1) the teacher role, 2) the student role, 3) instructional objective, and 4) instructional process. The essential features under each aspect are shown in Table 4.1 of Chapter IV.

Activity III: Reflecting on IBI

The purposes of Activity III were: 1) to promote the teachers' reflection on their teaching practices; and 2) to provide the opportunity for the teachers to learn IBI from reflection and communication with each other. After being introduced to the purposes of the activity, the teachers were asked to observe their own inquiry-based lessons via videos and wrote a reflection on their practices. These lessons were not the ones teachers presented. They were ones of the two lessons that the teachers did not choose to present. The researcher provided a reflective protocol for guiding the teachers to write reflection. This reflective protocol was similar to the one used for Phases 2 through 4 of the study (see Appendix A). To reflect on their practices, the teachers wrote their reflections and supported their ideas with empirical evidences. After having completed the writings, individual teachers shared their reflections and evidence with the CAR Team. The team members discussed together in order to set out the essential features of IBI that individual teachers already held and the ones that did not appear in their classes. After the discussion, the researcher summarized these features for the CAR Team. The features of IBI not present in these lessons were identified as the ones that needed to be emphasized in the teachers' upcoming lesson. Before ending the activity, the researcher showed an example of inquiry-based lesson plan (developed by the researcher) that represented the full set of essential features of IBI and provided a brief description of how the lesson was consistent with the crucial components of inquiry teaching.

Before completing the first central meeting, the researcher reminded the teachers of their role and commitments for Phase 2: CAR Cycle I. In that phase, the teachers were expected to plan, act, observe, and reflect on their new inquiry-based lessons. The lessons were designed based on the essential features of IBI identified and discussed with the group during Phase 1. To guide the teachers in planning and implementing their lessons, a summary of the essential features of IBI was given to the individual teachers. After that, the teachers were given documents for assisting them in extending their understanding of IBI. The documents included "Alternative Understanding of IBI" (National Research Council, 2000; Liewellyn, 2005) and "Science Process Skills" (Roadrangka and Dachakop, 1989).

Phase 2: CAR Cycle I

Phase 2 of the professional development program (CAR Cycle I) took place from November to the first week of December 2008. At the beginning of this phase, individual teachers designed an inquiry-based lesson plan according to the essential features of IBI. The teachers could select any science concept that they found appropriate for teaching through IBI. After designing their lesson, the teachers taught the lesson in their actual classrooms[2]. Their instruction was video-recorded and observed by the researcher. After the implementation, the teachers were interviewed individually regarding their teaching and understanding of IBI. The protocol for this second interview is provided in Appendix B. After the interview, the researcher provided suggestions and feedbacks for the teachers regarding the inquiry-based lesson plan, the lesson implementation, and the issues of IBI that teachers confronted difficulties in understanding and practice. The topics that the researcher has a conversation with the teachers are shown in Appendix D. The teachers were then given a DVD of the video-taped lesson. They were asked to watch their own teaching

[2] The three case study teachers implemented their inquiry-based lessons with the same class of students throughout the study.

and write a reflection on their practice. Finally, the teachers were asked to bring their taught-lesson plan and teaching experience to share with the CAR Team in the second central meeting.

Second Central Meeting

The second central meeting was scheduled on a holiday in December 2008. This meeting aimed: 1) to provide the teachers with the opportunity to share their lesson plans, teaching experiences, and difficulties in understanding and implementing inquiry-based lesson; 2) to assist and support each other in improving inquiry-based lessons; and 3) to learn IBI through reflection on their own instructions and communication with each other, and participation in activities provided by the researcher. There were two activities conducted in this meeting. A summary of the activities is provided as follows:

Activity I: Learning IBI through Sharing and Reflecting

The activity aimed to give the teachers the opportunity to share their teaching experiences and to learn IBI from each other. After being informed of the purpose of the activity, the teachers were invited to share their inquiry-based lessons. Similar with the Activity II of the first central meeting, the teachers presented their lessons by considering a set of guiding topics which included classroom context, teaching and learning objective, instructional process, the teacher role, the student role, and issues of concern. During the presentation, the researcher helped the audience to understand the classroom context and instruction by showing several pictures of classroom teaching. After the presentation of each teacher, the researcher encouraged the CAR Team members to reflect on their peer's practice through discussion. The reflection dealt with the essential features of IBI. During this reflection period, there was also an opportunity for the CAR Team members to critique the inquiry-based lesson, provide suggestions to their colleague for improving lesson, and support their peer's success. At the end of the activity, the CAR Team members tried to identify the essential features of IBI that individual teachers already included in the lessons and the ones that did not exist in any parts of their lessons. The absent features were the ones that were to be emphasized in the teachers' second inquiry-based lessons.

Activity II: Reflecting on Case Story

Activity II for the second central meeting was designed to provide the teachers with the opportunity to learn IBI through reflection on a case story of a science teacher who taught science through inquiry. This case story was translated and revised from "A Case Study: Inquiring about Isopods" (Liewellyn, 2005). The revision was prepared by including a framework of the essential features of IBI. The teachers read the story and then worked as a group to reflect on the story. During this procedure, the researcher acted as a moderator who raised questions for reflection. The teachers shared their ideas and supported these with elements from the story. The questions for reflection were asked sequentially according to the essential features of IBI. At the end of the activity, the CAR Team created a summary of what they had learned in terms of IBI.

Before ending the second central meeting, the researcher reminded the teachers of their role and responsibilities for Phase 3: CAR Cycle II. For the CAR II, the teachers were expected to plan, act, observe, and reflect on their new inquiry-based lessons that were designed based on the essential features of IBI. After the reminding, the teachers were given a reference to read to broaden their knowledge of IBI. The reference provided was "A Variation of Inquiry-Based Instruction" (National Research Council, 2000; DCID, 2002).

Phase 3: CAR Cycle II

Initially, the CAR Cycle II was planned to take place only in December 2008. However, during that timeframe there were a number of events in schools, such as a midterm examination, sport days, and the New Year celebration. As a result, the teachers did not have time to complete the new inquiry-based lessons in December. The CAR Team agreed to extend the phase to include January 2009. Therefore, Phase 3 took place from December 2008 to January 2009. Like the CAR Cycle I, the CAR Cycle II began with the development of inquiry-based lesson plans followed by the implementation of these lessons. During implementation, the researcher observed and video recorded the teachers' instruction. After that, the individual teachers were interviewed regarding their teaching and understanding of IBI. The researcher then assisted the teachers regarding the lesson plan, the lesson implementation, and the issues of IBI that teachers found difficult to understand and implement. The teachers then were given a DVD of their videotaped teaching to observe and write a reflection on their practice. The phase ended with a full day meeting of the CAR Team. The teachers were asked to bring their implemented-lesson plan and classroom instruction to share with the CAR Team in the meeting.

Third Central Meeting

The third central meeting was conducted on a Saturday in January 2009. The objectives for the meeting were: 1) to provide the teachers with the opportunity to share their lesson plans, teaching experiences, and difficulties in understanding and implementing inquiry-based lesson; 2) to assist and support each other in improving inquiry-based lessons; and 3) to learn IBI through sharing and communicating with each other. There was only one activity in this meeting. It was because the researcher intended to provide the teachers time and support for opening the communication (Zuber-Skerritt, 1991; McNiff *et al.*, 1996; Kemmis and McTaggart, 2000). After informing the teachers of the purpose of the meeting, the researcher introduced the activity to the group.

Activity I: Learning IBI through Sharing and Communicating

In this activity, like the Activity I of the second central meeting, teachers were given the opportunity to share their inquiry-based lessons, teaching experiences, as well as difficulties and concerns with the CAR Team. The teachers presented their lessons by describing the four aspects of the essential features of IBI. After the presentations of each teacher, there was an opportunity for the CAR team members to critique the inquiry-based lesson, provide suggestions to their colleagues for improving lessons, and support their peer's success. Interestingly, the CAR Team took approximately one and a half hours to critique and to advise each teacher on their instructional practice. At the end of the activity, the CAR Team members identified the essential features of IBI that the teachers already had included and the ones that did not appear in their lessons. The missing features were the ones that served as the focus for the third (and final) inquiry-based lessons of the teachers.

Before completing the third central meeting, the researcher reminded the teachers of their role and responsibilities for Phase 4: CAR Cycle III. Like previously, the teachers were expected to plan, act, observe, and reflect on their new inquiry-based lessons. The researcher emphasized that the teachers were to design the last lesson by considering the essential features of IBI. There was no document for further reading given in this meeting.

Phase 4: CAR Cycle III

The CAR Cycle III took place from the last week of January to the end of February 2009. Overall activities done in this phase were similar to the ones occurred in the CAR Cycle I and the CAR Cycle II. At the beginning of this phase, individual teachers designed an inquiry-based lesson plan based on the essential features of IBI. After that, they taught the lesson in their classrooms. The researcher observed and video recorded the teachers' instruction. The teachers were then interviewed individually regarding their teaching and understanding of IBI. In addition, they were asked to describe their thinking and/or feeling about the CAR Program. The researcher then assisted the teachers regarding the lesson plan, the lesson implementation, and the issues of IBI that were of concern to the teachers. After that, the teachers were given a DVD on their teaching to observe and write a reflection. Ultimately, the teachers were involved in the fourth central meeting.

Fourth Central Meeting

The fourth meeting was organized to take place on the last Saturday in February 2009. This meeting was designed to provide the teachers with the opportunity to share lesson plans, teaching experiences, and difficulties in understanding and the practice of inquiry-based lesson; to assist and support each other in improving inquiry-based lessons; and to learn IBI through sharing and communicating with each other. The activity for this meeting was the same as the one completed at the third central meeting. The only exception was that at the end of this meeting the teachers did not design a new inquiry-based lesson.

In summary, the professional development program employed in this study encompassed a period of time of approximately 8 months. The lower secondary level science teachers learn to change their understandings and practices of IBI in the context of the CAR Program within which they participated in one-to-one and central meetings and worked through three cycles of action reflection cycles. A diagram of the CAR Program is provided in Figure 3.1. A schedule of all meetings with the teachers is displayed in Appendix C. A description of activities and data collection evenet throughout the study is shown in Appendix D.

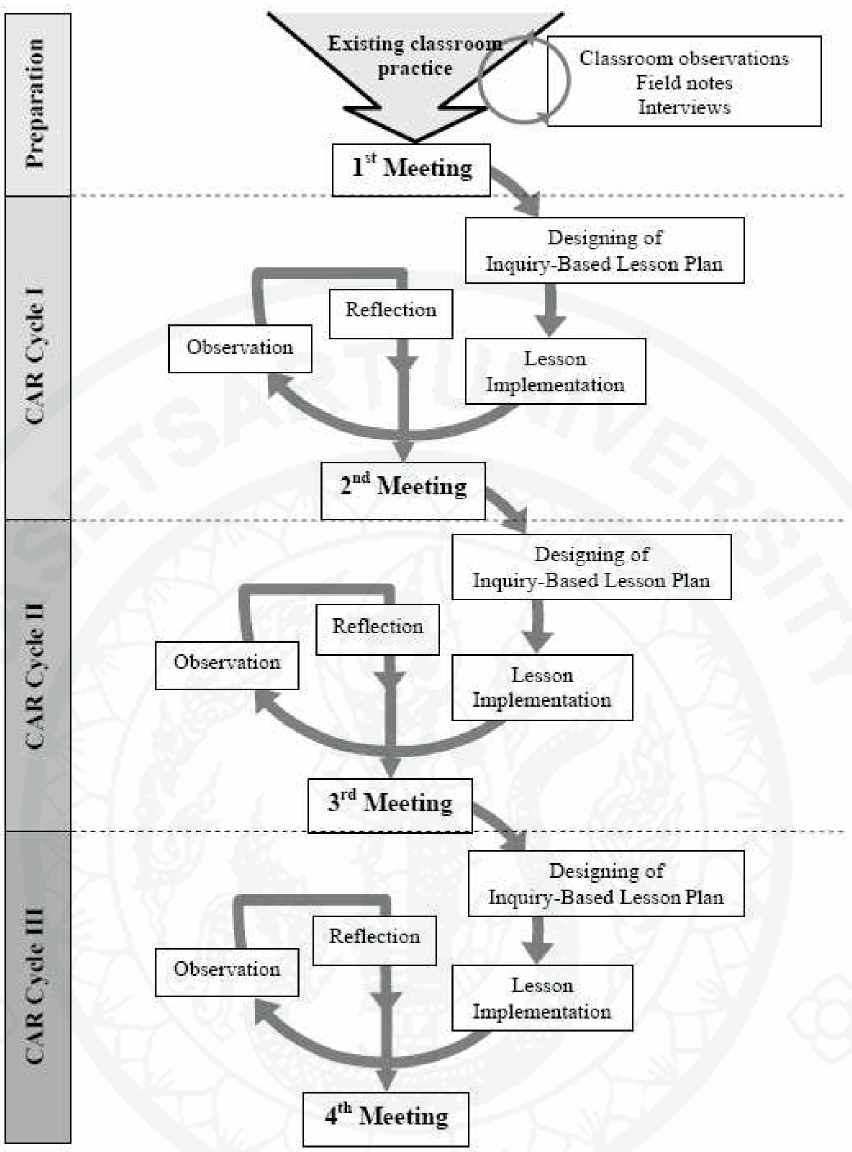

Figure 3.1 Diagram of the CAR Program

Data Collection

For this study, the data was gathered from multiple sources. Multiple data sources enable the researcher to access a comprehensive perspective on a natural social setting due to the fact that there is no single source can do (Patton, 2001). Using a combination of data types also improves the credibility of the study. The strengths of one source can commensurate for the weakness of another source (Marshall and Rossman, 2006). The data collection methods utilized in this study included semistructure interviews, classroom observations, teacher's inquiry-based lesson plans, teacher's written reflections and central meetings. The data collection used in the study is described below.

Individual Interview

Interview is the primary data gathering method used for accessing the teachers' understanding in this study. For Fontana and Frey (1994), interview is the most powerful method for understanding human beings. It is suitable for collecting data that researchers can not directly observe from people or events (Patton, 2002). The researchers have to ask people questions in order to understand what they think about what has happened. Semi-structured interview is a type of interview employed in the study. This kind of interview includes a series of questions that are designed to obtain specific answers from the respondents. However, the questions are flexible in their form and sequence (Kvale, 1996). This flexibility enables the researcher to follow up the respondents' answers and capture any changes in their understanding. It is also provides the respondents with the freedom to answer the questions and add their points of view.

In the current study, semi-structured interviews were conducted with individual teachers on four separate occasions. The first interview was performed at the beginning of the Preparation Phase, before the teachers received any experiences from the professional development program. The second, third, and forth interviews were employed after the teachers implemented their inquiry-based lessons in the CAR Cycle I, the CAR Cycle II, and the CAR Cycle III, respectively. The interviews were scheduled, conducted in Thai language, audio-recorded, and lasted approximately 50 minutes. All interviews were performed at either teacher's science classroom or office. The first interview focused on three areas: 1) science teaching experiences and teaching styles; 2) current understanding of IBI; and 3) the reasons and expectations for participating in the CAR Program. The second, third, and fourth interviews emphasized only on teacher's understanding of IBI. The interviews were transcribed verbatim and used as primary source of data for exploring the changes of teacher's understanding of IBI. The interview protocol is shown in Appendix B.

Inquiry-Based Lesson Plan

Review of documents is the method used in this study to supplement the data gathered from interviews. As Yin (2002) writes, the most important use of documents in case studies is to corroborate and augment evidence from other sources. Documentary evidence portrays values and beliefs of participants in the setting (Marshall and Rossman, 2006). It reflects the participants' perspective (Merriam, 1998). According to Marshall and Rossman (2006), documents could be either ones produced in the course of everyday events or ones constructed specifically for the research. In the case of this study, the document is specifically designed for the study. It is the teacher's inquiry-based lesson plan. Although lesson plan is a written document that the Thai teachers routinely produce before implementing their lesson; in this study, the teachers were asked to design lesson plans according to their initial understanding of IBI and their understanding after experiencing each phase of the professional development program. Each individual teacher wrote six inquiry-based lesson plans. The first three lessons were done in the Preparation Phase while the others were written in the CAR Cycle I, the CAR Cycle II, and the CAR Cycle III, respectively. In general, the lesson plans were composed of eight components: the science standard, expected learning outcome, learning objective, a summary of the concept being taught, the teaching and learning process, a list of instructional material or equipment, assessment and evaluation, and the worksheet being used. A lesson plan could span from one to five periods, depending on the teachers. The data gathered from lesson plans was assumed to reflect what the teachers knew in terms of IBI.

Classroom Observation

Given that the study aims to investigate the science teachers' teaching practice of IBI before and after they participate in the CAR Program, classroom observation seemed to be most appropriate method for addressing this purpose.

According to Patton (2001), observation allows researchers to construct a better understanding of the context in which the participants interact. It also broadens the researchers' ability to explore motivations, beliefs, concerns, interests, and biases of the people being observed (Lincoln and Guba, 1985). In this study, classroom observation serves as a primary source of data which is used for uncovering what the teachers do in relation to IBI in their science classes before and after they engage in the CAR Program. The form of classroom observation taken in this study is non-participant observation. In this regard, the researcher acts as a witness who observes the teaching without interrupting the instruction being observed. When doing an observation, the researcher locates herself at the back of the classroom. She monitors the teachers' teaching and takes field notes. Both teacher and students recognize her identity as a researcher.

According to Patton (2001), the focus of observation is dependent on the framework or focus of the study. In the case of this study, the focus is on the science teachers' understanding and practice of IBI before and after they engage in the professional development program. Therefore, the focus of classroom observation is framed by the scope of the essential features of IBI:

a) The role of the teacher

Activity director, Facilitator, Guide, Motivator

b) The role of the student

Active investigator, Minds-on investigator

c) Instructional objective

Scientific knowledge, Science process skills, Scientific attitudes

d) Instructional process

Classroom introduction: Prior knowledge, Motivation, Scientifically oriented question

Investigation: Scientific investigation, Data collection

Conclusion/Explanation: Data analysis, Conclusion based on evidence, Connection between conclusions with prior knowledge, Connection between conclusions with related concept

Communication: Communication of data, Communication of conclusion, Justification and evaluation of data and conclusion

Group Work: Encouragement of collaborative group work, Roles and duties of students in groups

In the study, the researcher began to collect data via classroom observation in the Preparation Phase. During this phase, the researcher observed three inquiry-based lessons for each teacher. A lesson spanned from 1 to 2 periods (an hour/period). In the following three phases, the researcher observed one lesson for individual teachers in each phase. The lessons of these three phases ranged from 3 to 5 periods.

For all observations the instruction was video recorded. To provide a complete record of what has happened in the classroom, video recorder is a useful instrument that can extend the researcher's capability for observation (Lincoln and Guba, 1985). The video recorder was also fruitful in terms of its utility, as it facilitated the teachers to observe their own practices. In the central meetings, video recorder also helped the CAR Team to visualize the teacher's classroom context and teaching practice. Nevertheless, it is important to note that the researcher visited the teachers' schools and classroom several times before starting to video-record. The school/classroom visits were used to ensure the accuracy of the activities being observed and for promoting normal practices of both teacher and students. It could also promote a confidence and familiarity among researcher, teacher, and students. The pilot video-recording of the classroom activity before starting the actual data collection process was also useful for the teacher and students in getting them prepared for being recorded, so that they could act naturally in their classes.

Written Reflection

The teacher's written reflection is another method of data collection employed in this study. According to action research, reflection is a crucial step that practitioners learn to solve their practical problems and refine their practice (Kemmis and McTaggert, 1998). For this study, reflective writing is a method chosen for verifying evidence obtained from classroom observation. Prior to the actual data collection process, the teachers practiced their reflective writing. The practice was used for helping the teachers to learn how to reflect on their practice and for assisting them with any difficulties they found in writing. Throughout the study, individual teachers wrote six reflections on their inquiry-based lessons. The teachers wrote one reflection after implementing each lesson. They were provided with a DVD of their teaching practice for observing and then reflecting. For guiding the teachers to reflect profoundly on their actions, a reflective protocol was given to individual teachers. The reflective protocol is shown in appendix A.

Group Discussion

As a basis of collaborative action research, practitioners learn to solve their practical problems and construct new knowledge through collaborative working with their colleagues (Oja and Smulyan, 1989). Practitioners' learning experiences are opened while they communicate with team members. In this study, the three science teachers were involved in the discussion of the CAR Team in the four central meetings at the end of each phase. During each meeting, the teachers brought their lesson plans, teaching experiences, and problems/concerns they confronted in understanding and teaching IBI to share with the CAR Team. The CAR Team members then critiqued the inquiry-based lessons, provided suggestions to their colleague for improving their new lessons, supported their peer's success, and finally summarized of what they learned regarding IBI. The four meetings were video-recorded. Relevant parts of the conversations of the CAR Team were transcribed and used for tracking what the teachers understand and practice with regarding to IBI after they engaged in the CAR Program.

Data Analysis

Most common data analysis used in qualitative studies is the inductive approach. Inductive data analysis allows findings to emerge from data rather than setting up abstractions, concepts, hypotheses, or theories beforehand (Merriam, 1998). Within-case analysis and cross-case analysis are forms of inductive analysis used in this study. The data from individual teachers was initially analyzed through a within-case analysis and followed by a cross-case analysis. To address the research questions, individual interviews, teachers' inquiry-based lesson plans, classroom observations, teachers' written reflections, and group meetings were analyzed. The analytic procedure of this study is described as follows:

1. All data was organized into a form that could be easily referenced.

2. The entire data set of the individual case was read. The researcher became initially familiar with the data (Marshall and Rossman, 2006).

3. The entire data set was read second time. While reading through this data set, the researcher coded and jotted down notes and comments. These notes were known as "units of data" which they were referred to bits of information that the researcher found interesting, potentially relevant, or important to the study (Merriam, 1998).

4. Categories were generated based on units of data and their relevant with the research questions.

5. Relevant categories were clustered into themes.

6. The themes were interpreted. Interpretation brought meaning and coherent to the themes (Marshall and Rossman, 2006).

7. The themes were verified by searching for evidence that could produce alternative explanations. The researcher searched through the entire data for negative instance of themes (Marshall and Rossman, 2006).

8. The themes from a case were constantly compared with other cases.

9. The themes that were found across the data of individual cases and relevant to the research questions became the common findings.

The findings are initially reported in a qualitative case study, which provides themes and thick descriptions of each individual case. This is followed by the results from cross-case analysis which provides common findings across the three cases. The findings of individual teachers' understanding and practice of IBI before engaging in the CAR Program are reported in Chapter IV. The three teachers' knowledge and their use of IBI after they participated in the CAR Program are provided in Chapter V.

Trustworthiness of the Study

In qualitative research, the quality of studies is ensured through specific criteria including credibility, transferability, dependability, and conformability (Lincoln and Guba, 1985). A combination of these four criteria is referred to "trustworthiness". The four criteria are equivalent with the terms used in quantitative inquiries which include: internal validity, external validity, reliability, and objectivity. According to Lincoln and Guba (1985) and also Tippins (2006), credibility refers to whether the findings obtained from this study are credible or believable from the participants' perspective. Transferability is concerned with whether the findings obtained from the study can be applied or transferred to other contexts or participants. Dependability refers to the degree to which the findings obtained from the study would be repeated if researchers could study the same thing twice. Confirmability is established if the findings of the study are the result of the study and not a simply a reflection of the biases of the researcher. Thus, the findings could be confirmed or corroborated by the others.

There were several techniques used in this study for ensuring trustworthiness. Credibility of the study was achieved through the use of prolonged engagement, triangulation, and member checks (Lincoln and Guba, 1985). The researcher studied the participants in their school contexts for a substantial period of time. Through engaging in the school contexts, the researcher gained the confidence of the teachers, understood the school contexts, and learned to construct the meanings from teachers' perspectives. Triangulation in this study was refers to the use of multiple data collection methods and multiple data sources. Triangulation helped to overcome the weakness and bias of using a single source or method (Denzin, 1989). Member checking was another technique used to promote credibility of the study. The teachers were given a copy of transcripts and interpretations of the data gathered from the interviews to check whether the transcripts and the interpretations were consistent with their answers or meanings. Transferability of the study was accomplished through the use of thick description (Lincoln and Guba, 1985). The researcher described the school contexts, background of the teachers, and other factors that would affect the teachers' understandings and practice of IBI. Thick description also helps the readers to make judgments about the applicability of the findings. Dependability and confirmability of the study were approached through use of an audit trail (Merriam, 1998). It was impossible for most researchers to study or gather the same thing twice. Thus, the best they can do is to describe how they arrive at their findings (Dey, 1993). In this study, the researcher provided details of the research site, the participants, the research design, the data collection methods, the data analyses, and the interpretations of the data. These details should enable other experts to review and audit whether the interpretations are supported by the inquiry.

CHAPTER IV

TEACHERS' UNDERSTANDINGS AND PRACTICES OF INQUIRY-BASED INSTRUCTION BEFORE THE COLLABORATIVE ACTION RESEARCH PROGRAM

Introduction

This chapter presents results of three case study teachers before they engaged in the Collaborative Action Research Program [CAR Program]. The chapter aims to address the first research question: the Thai science teachers' understanding and practice of inquiry-based instruction before they participated in the CAR Program. The chapter begins with an explanation of the essential features of inquiry-based instruction [IBI] which are used as a framework for the data analyses. This section is followed by each teacher's background information. The results of the teachers' understanding and practice regarding IBI before the CAR Program are then provided. Finally, the common findings across the three case study teachers are illustrated and discussed. Throughout this chapter, pseudonyms are used to represent the case study teachers' names; these are Mr. Phichit, Mr. Monsid, and Mr. Suriya as well as the teachers' schools; Thai Authid School and Pracha-niyom School.

Essential Features of Inquiry-Based Instruction

The aims for having these essential features of IBI are to guide the teachers in planning, implementing, observing, and reflecting upon their IBI and to provide the researcher a framework for conducting interviews, classroom observations, and data analyses. These essential features were derived from the goals of science teaching and learning, the role of teachers and students in science classroom, and the inquiry-oriented activities suggested by the NSCS (DCID, 2002: 3, 35-36), the 5Es inquiry process guided in the Manual of Science Teaching and Learning (DCID and IPST, 2002: 79-80), the scientific inquiry defined by the NSES (National Research Council, 1996: 23) and the essential features of classroom inquiry (National Research Council, 2000: 24-27) as well as the participating teachers' prior knowledge of IBI (see Activity II in the first central meeting in Chapter III). The essential features of IBI of the study covered four aspects involving: 1) the role of the teacher, 2) the role of the student, 3) instructional objective, and 4) instructional process. A brief description of the essential features is displayed in Table 4.1.

Table 4.1 Essential Features of Inquiry-Based Instruction

Essential Features of Inquiry-Based Instruction		
Aspects		**Descriptions**
Role of Teacher		Activity director, Facilitator, Guide, Motivator (DCID, 2002; DCID and IPST, 2002)
Role of Student		Active investigator, Minds-on investigator (DCID, 2002; DCID and IPST, 2002)
Instructional Objective		To learn scientific knowledge, science process skills and scientific attitudes in relation to the expected learning outcomes for 7th – 9th grade students consistent with the NSCS. (DCID, 2002; DCID and IPST, 2002)
Instructional Process	Classroom Introduction	1. Inquiry process begins with question(s) that students are interested in and/or curious about (National Research Council, 2000; DCID, 2002; DCID and IPST, 2002).
		2. Inquiry process begins with scientifically oriented question(s) (National Research Council, 2000; DCID, 2002; DCID and IPST, 2002).
	Investigation	3. Scientifically oriented question is answered by scientific investigation (DCID, 2002; DCID and IPST, 2002).
		4. Students, the teacher, or both parties design(s) an investigation (DCID, 2002; DCID and IPST, 2002).
		5. Students conduct an investigation and collect data (DCID, 2002; DCID and IPST, 2002).

Table 4.1 (Continued)

Essential Features of Inquiry-Based Instruction		
Aspects		**Descriptions**
Instructional Process (Continued)	Conclusion / Explanation	6. Students, the teacher, or both parties analyze(s) data gathered from an investigation (National Research Council, 2000; DCID, 2002; DCID and IPST, 2002).
		7. Students formulate a conclusion/explanation from evidence and their prior knowledge to address the scientifically oriented question (National Research Council, 2000; DCID, 2002; DCID and IPST, 2002).
		8. Students, the teacher, or both parties connect(s) the conclusion/ explanation to scientific knowledge (National Research Council, 2000; DCID, 2002; DCID and IPST, 2002).
	Communication	9. Students communicate and justify their conclusion/explanation with other students (National Research Council, 2000; DCID, 2002; DCID and IPST, 2002).
		10. Students evaluate their conclusion/explanation in the light of alternative ones, particularly those reflecting scientific understanding (National Research Council, 2000; DCID, 2002; DCID and IPST, 2002).
	Group Work	11. Students have a chance to learn through social interaction during group work (DCID, 2002; DCID and IPST, 2002).

Background Information

Case I: Mr. Phichit

Teacher's Background

Phichit was 29 years old. He had 7 years of science teaching experience leading into the 2008 academic year. Phichit taught at Thai Authid School, a suburban lower secondary school governed by the Bangkok Metropolitan Administration [BMA]. He received a scholarship from the Project for the Production of Science and

Mathematics Talented Teachers [PSMT] to study at the undergraduate and diploma education levels. The PSMT project was sponsored by the IPST. The PSMT project gives funding for those who have high achievement scores in science and mathematics and want to be science or mathematics teachers. Phichit completed a Bachelor of Science degree, majoring in Applied Biology, and a diploma's degree in the teaching profession. He pursued both degrees from Rajabhat University in the province of Ayutthaya. Phichit also had a master's degree in Science Education from a government university in the province of Phitsanulok. He completed his master's degree one year before participating in this study.

In the 2008 academic year, Phichit had 21 hours a week of teaching responsibility. He spent 15 hours teaching General Science in 7^{th} and 8^{th} grade. Phichit also taught Fundamental Vocation for 3 hours while the remaining 3 hours he devoted to Science Club, Scouts, and counseling subjects. Phichit indicated that his non-teaching assignments consisted of being a homeroom teacher, head of the science department, head of the lower secondary level, and member of the audiovisual section. During the past three years, Phichit had attended several workshops organized by outside school agencies. However, none of them were related to IBI. Phichit noted a number of the workshops were held on weekdays. To attend these workshops, he had to leave his class with other teachers. The teachers typically taught their subjects (e.g., mathematics or social science) in his period rather than science. In addition, Phichit had limited time for preparing science lessons, as well as teaching.

In the first interview, Phichit indicated what his teaching styles in the General Science subject consisted of. Phichit taught science by having students do experiments, review data, conduct explorations, and write reports. He also gave students lectures. In classroom observations[3], it was found that science teaching in Phichit's classroom included the activities of reviewing concepts from the previous lesson, discussions,

[3] The observations were part of school visits during the Preparation Phase. These visits intended to produce trust and familiarity with the teachers and students, as well as to explore teachers' existing classroom practices. Therefore, the teachers were free to select an instructional approach whether it was inquiry-based instruction or not.

student assigned tasks, presenting work, and giving lectures. Phichit expressed several reasons for participating in the study. He wanted to improve his science instruction through IBI, particularly lesson introductions, motivating students' interest, and engaging them in the inquiry process. Phichit thought the CAR Program would provide an opportunity for him to learn to develop his teaching practices.

Students' Background

In this study, classroom observations were conducted with a class of 8^{th} graders. This class contained 37 students, comprised of 19 females and 18 males. Most of the students were from working-class families and did not live residentially in the vicinity of school communities. Rather, they migrated from other areas following their parents or relatives who came to the city for work. Many of the students had an average to low achievement scores in science while they were in 7^{th} grade.

In the first meeting, Phichit expressed his concerns regarding students. He believed that students lacked basic knowledge. They had less experience relating to science. When he had a discussion with them, many students could not share their thoughts. Phichit thought it was because students did not have knowledge and experience about the topics of discussion. Therefore, Phichit believed to be successful in learning science through IBI, students had to have basic knowledge about the concepts of study. In addition, Phichit revealed that more than 90% of the students in the class had family problems. Furthermore, a number of the children's families were at an economic disadvantage. Parents could not take good care of their children's education. As a result, for many students, education was not a goal in their lives.

With respect to the relationship between Phichit and his students, it was found that he had a good relationship with students. In the first meeting, Phichit stated that he viewed himself as a brother or a friend to the students. He usually spoke informally to them during his lessons. They did not feel unfriendly with him. Phichit thought because of this kind of relationship, the students were eager to ask questions and talked openly with him.

Classroom Setting

In this study, the observations of Phichit’s instructional practices were conducted in a science laboratory room. The laboratory room had fewer science supplies than ordinary science laboratory rooms. There were no gas and water supplies in the room. The six lab tables were organized in the middle area of the room. Each table was surrounded by 6-7 chairs. There was a large blackboard permanently connected to the wall in front of the room. Audiovisual equipment was kept on the right side of the blackboard while a shelf filled with DNA models and microscopes was placed on its left side. The teacher’s table was located nearby the blackboard. There was an unusable sink at one end of the teacher’s table. On the right side of the room, there were two cabinets filled with supplies, glass, hardware, lab equipment, and chemical substances. On the left side of the room there were bookshelves filled with textbooks and some lab equipment. There was a small human body model, a balance, and numbers of clamp holders and stands on top of the bookshelves. Windows were also located along this side. In the back of the room there were bookshelves with textbooks and supplemental books. Science charts were hung on the wall on top of the bookshelves and portraits of a monk and the royal family were located above the science charts. During classroom observations, the researcher located herself at the back of the room, close to the back door. The layout of science laboratory room is shown in Figure 4.1.

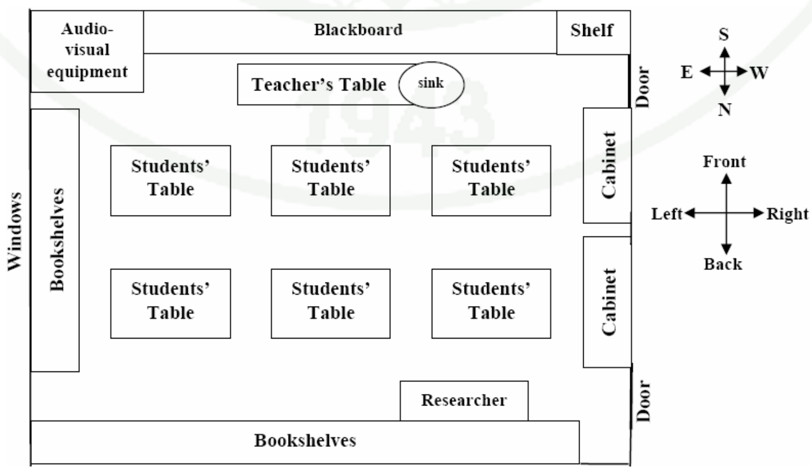

Figure 4.1 Layout of Thai Authid School’s Science Laboratory Room

Case II: Mr. Monsid

Teacher's Background

Monsid was 32 years old. He was an experienced science teacher in his 11th year of science teaching leading into the 2008 academic year. Monsid and Phichit were colleagues. They both taught at Thai Authid School and the school had only two science teachers who taught 7th-9th grade students. However, Monsid began his teaching carrier at another school. He taught Chemistry for one and a half years at a private school in Bangkok. Then, he was hired by the BMA to teach at Thai Authid School beginning in 1997. Monsid has a Bachelor of Education degree, majoring in Chemistry Teaching from the Institute for Teacher Preparation in Bangkok. During the school visit it was found that Monsid did not want to be a teacher. He wanted to be an electrician. However, his father wanted him to be teacher.

In the 2008 academic year, Monsid was responsible for a teaching duty of 12 hours a week. He spent 6 hours teaching General Science in 9th grade. Monsid taught Fundamental Vocation for 3 hours while the remaining 3 hours he used for teaching Agriculture, Scouts, and counseling subjects. Monsid indicated that his non-teaching duties included being a homeroom teacher and head of several upcoming activities during the school year, such as a Botanical Project, Science Week, and Sports Day. During the past three years, Monsid had attended a number of workshops organized by outside school agencies. However, none of them were related to IBI. Monsid indicated that most workshops and activities occurred on weekdays. He then had limited time for preparing and teaching science. Although Monsid did not have time, he decided to participate in the study. Monsid reasoned the CAR Program would motivate him to improve his instruction. Monsid noted he always enjoyed trying new things in his classroom. In this case, Monsid viewed the CAR Program as a new thing that would be enjoyable to engage in and learn.

According to the first interview, Monsid indicated teaching science in his lessons included a variety of activities such as having students conduct experiments, observe demonstrations, listen to his narrations of scientists' histories, participate in discussions, and invent some products. Data from classroom visits supported that Monsid used these activities in his lessons. With respect to the relationship between Monsid and his students, the data indicated that Monsid was pleasant with students. In the first meeting, Monsid indicated that he typically established a friendly atmosphere with his students in his lessons. He viewed himself as a brother to the students. Monsid did not want students to fear him. Rather, he wanted them to trust and respect him.

Students' Background

In this study, classroom observations were completed within a class of 9th graders. The class contained 33 students, comprised of 15 females and 18 males. Most of the students' parents were at an economical disadvantage. Many of them were not residents of Bangkok. They came to the city for work. The majority of the students had average to low achievement scores in science while they were in 8th grade.

In the first meeting, Monsid mentioned his concerns regarding students. He revealed that around ninety percent of his students were unable to pass their final examination. Monsid noted his students were not interested in education. They did not value education as important in their lives. Almost all of the students also were confronted with family problems.

Classroom Setting

In this study, the observations of Monsid's instructional practices were conducted in two rooms: the science laboratory room and the 9th graders' classroom. The science laboratory room was described previously in Case I: Phichit. It was the same room as Phichit used in his lessons. The 9th graders' classroom arrangement was totally different from the lab room. The students' seats were organized in two columns. There was one blackboard and one whiteboard permanently connected to the wall in front of the room. A television was located on top of the boards. The teacher's desk was situated nearby the whiteboard. Windows were located along the right side of the room. There was no decoration on the wall of the left side of the room. Two bookshelves filled with textbooks were placed in the back of the room. On top of the bookshelves, there were three boards filled with announcements and students' work from other subjects (e.g., Mathematics, English). During classroom observations, the researcher located herself to the back of the room, close to the back door. An overview of the 9th graders' classroom is displayed in Figure 4.2.

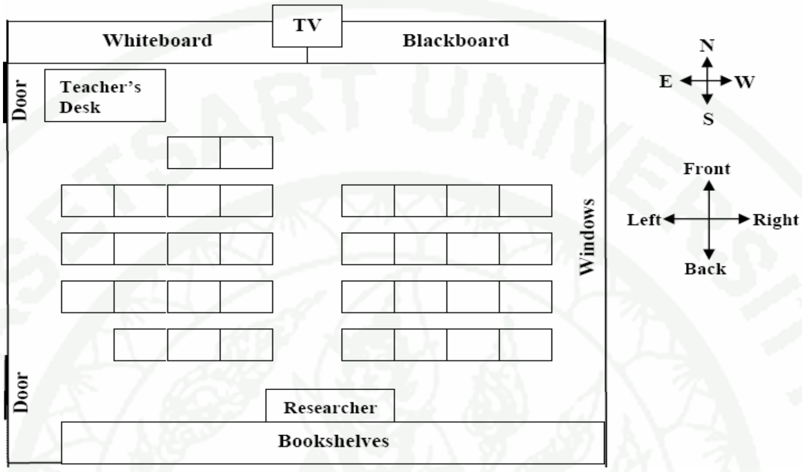

Figure 4.2 Layout of Thai Authid School's 9th Graders' Classroom

Case III: Mr. Suriya

Teacher's Background

Suriya was 51 years old. He had 33 years of teaching experience and 11 years of science teaching experience leading into the 2008 academic year. Suriya taught at Pracha-niyum School, a suburban lower secondary school governed by the BMA. However, he began his teaching carreer at another school. Suriya had taught English at an elementary school governed by the BMA for 20 years. After completing his master's degree in 1997, he moved to Pracha-niyum School and began his teaching carreer as a science teacher. He taught General Science in the 7th-9th grades. Suriya pursued a Bachelor of Education degree, majoring in Physics Teaching and a master's degree in Adult Education from the Institute for Teacher Preparation in Bangkok. In a school visit, Suriya indicated that he did not have profound content knowledge in some science area, particularly in biology. This may have been related to the fact that he did not teach science during the first 20 years of his teaching carreer. The data also showed that Suriya did not want to be a teacher. He expected to be an engineer. However, he could not pass an entrance examination. Thus, Suriya decided to study education and became a teacher. In addition, Suriya did not want to teach at a school governed by the BMA. He desired to work in an administrative position at a school governed by the Office of the Basic Education Commission [OBEC]. Suriya indicated that he had previously submitted a request form to move to a school governed by the OBEC, but that request had not been approved.

In the 2008 academic year, Suriya was responsible for teaching 17 hours a week. He taught General Science in 9^{th} grade for 15 hours. Suriya spent the remaining 2 hours with Science Club and Scouts. The teacher indicated his non-teaching assignments to include being a homeroom teacher, member of the administrative section, member of the school activity section, and member of the audiovisual section. During the past three years, Suriya had attended several workshops organized by outside school agencies. However, they were not related to IBI. Suriya shared his concern regarding science instruction in a school visit. His anxieties included a lack of learning materials, a lack of time for covering all science concepts, and a lack of some science content knowledge. Suriya expressed his reason for participation in the CAR Program. He believed IBI was an effective approach for teaching and learning science. To participate in the CAR Program, Suriya hoped to learn new techniques and/or strategies for teaching science through IBI.

During the first interview, Suriya indicated that teaching science in his lessons included activities such as having students do experiments, conduct surveys, and carry out science projects. He believed he taught science through IBI frequently in his lessons.

Students’ Background

In this study, classroom observations were conducted with a class of 9^{th} graders. The class was comprised of 42 students. There were 30 females and 12 males. The majority of the students’ families were economically disadvantaged. They were workers, merchants, or agriculturists. A number of students had average to low achievement scores in science while they were in 8^{th} grade.

In the first meeting, Suriya commented about how his students had low motivation to study and that the students were not enthusiastic about learning science. They were not interested in whatever activities he provided. Suriya thought the main factor might be the students' families. According to Suriya, the parents were not concerned about their children's education. He added that some students came to the school without any learning materials. Some did not even have a pen. Suriya believed the students came to school because they had to come. It was not because they wanted to learn.

It was found that there was an uneasy relationship between Suriya and his students. In the first meeting, Suriya indicated that he had students evaluate his science teaching at the end of the first semester. He found that many students did not like the subject, or the teacher. One student wrote that he did not see a benefit of learning science and did not know why he had to learn this subject.

Classroom Setting

In this study, the observations of Suriya's instructional practices were conducted in a 9^{th} graders' classroom. The students' seats were organized in groups, as shown in Figure 4.3. Each group contained 3-4 students. There were two blackboards permanently connected to the wall in front of the room. A television was placed on top of the boards. The teacher's table was situated nearby one blackboard. Windows were located along the right side of the room. There was no decoration on any of the walls. A small area in the back of the room was devoted as a shelf filled with the students' drinking cups. During classroom observations, the researcher located herself to the back of the room. An overview of the 9^{th} graders' classroom is displayed below.

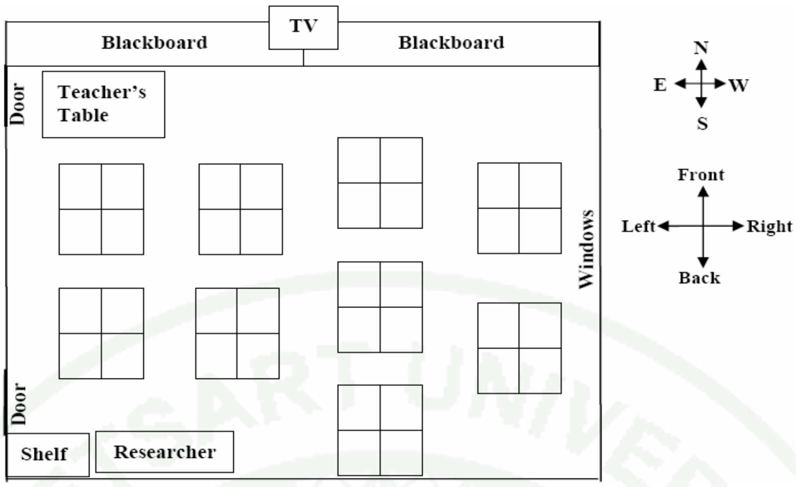

Figure 4.3 Layout of Pracha-niyom School's 9th Graders' Classroom

Teachers' Understandings and Practices of Inquiry-Based Instruction before the Collaborative Action Research Program

This section provides results from the Preparation Phase – the period of time before the three case study teachers received professional development experience from the CAR Program. To illustrate the teachers' understanding and practice of IBI, each teacher was interviewed individually regarding his understanding of IBI. Each individual teacher then designed and implemented three inquiry-based lesson plans centered on his initial understanding of IBI. The instructions were observed and video recorded. For Phichit, the three lessons included: 1) Heat and States of Matter; 2) Matter as Particles; and 3) Introduction to Chemical Reactions. Phichit implemented the lessons by following the 5Es inquiry process (DCID and IPST, 2002). This process is the one set out for teaching scientific inquiry by the Institute for the Promotion of Teaching Science and Technology [IPST] in Thailand. The 5Es inquiry process involved five procedural elements: engagement, exploration, explanation, elaboration, and evaluation. Monsid taught three lessons including: 1) Electrochemical Cell: Direct Current Source; 2) Dynamo: Alternating Current Source; and 3) Electric Circuits: Series and Parallel. Monsid implemented his lessons by following a numerical sequence in the lesson plans. For Suriya, his lessons were: 1) Planets in the Solar System; 2) Gravity; and 3) Linear Motion of Objects. Suriya taught the lessons by following a three step process involving: introduction, instruction, and summary. After implementing each lesson, the individual teachers then wrote a reflection on his classroom practice. In the end of the Preparation phase, the three teachers brought their lesson plans and teaching experiences to share and reflect with the Collaborative Action Research Team [CAR Team] in the first central meeting at Kasetsart University. The teachers' understanding and practice were analyzed from multiple data sources including individual interviews, teachers' inquiry-based lesson plans, teachers' written reflections, classroom observations, and the first central meeting. The data was analyzed by comparing each teacher's understanding and instructional practice to the four aspects of the essential features of IBI. The results are initially presented as individual cases. This is followed by common findings that emerged from a cross-case analysis.

Case I: Mr. Phichit

The Role of the Teacher: Teacher should be a guide and a motivator; however, in practice the teacher is also an activity director and a lecturer.

Before engaging in the CAR Program, Phichit viewed his roles in inquiry-based classroom as a guide and a motivator. As Phichit responded during the first interview, "In inquiry teaching, I think the teacher should be a person who persuades, guides, and motivates students to acquire knowledge. The teacher should encourage students to think step by step." (Phichit's interview #1: August, 2008). As Phichit stated, "I believed my role in this lesson was a guide. For the most part of the lesson, I advised and motivated students to think, to discussion with each other and to make conclusion. (Activity I of the first central meeting: October, 2008). Data from lesson plans also supported the idea that teacher as motivator. In his three lessons, Phichit planned to introduce the lessons by a motivational activity.

With regard to Phichit's teaching, the findings showed that his practice partially coincided with his understanding. In practice, Phichit was a guide, a motivator, an activity director and a lecturer. The classroom observation data illustrated that Phichit guided students to formulate hypotheses, do investigations, record data, analyze the data, and make conclusions, as evident in the excerpt below.

Phichit:	What average temperature is it? Can you calculate the average temperature of each state? To calculate the average temperature is to sum all the temperatures first, then divide the total by 6 (wait for students to calculate). How many do you get?
Students:	0 degrees, 2 degrees, 93.3 degrees, and 98.1 degrees.
Phichit:	(write students' answers on blackboard) Do you see? What increased?
Students:	Temperature.
Phichit:	If temperature increases, how does it affect the state of water?
Students:	It will change.
Phichit:	It will change from what? From solid to what?
Students:	Liquid, and from liquid to gas.
Phichit:	What is the temperature of solid water?
Students:	0 degrees.

(Phichit's classroom observation #1: August, 2008)

In his classroom instruction, Phichit also played the role of motivator. He motivated students' interest at the beginning of his three lessons. In the first lesson, Phichit had students observe water and ice and then discuss together about the two states of water and heat was a factor that affected the states of matter. In the second lesson, students were asked to shake a box of beads and observe the beads. The beads were supposed to represent particles of matter in a solid state. Phichit and students discussed data from the observation together. In the last lesson, Phichit motivated students' interests by having students observe the burning processes of candles and matchsticks and then discussed this phenomenon with them.

The classroom observation data showed that the teacher role was also as an activity director. In Phichit's teaching, students explored and experienced materials by following Phichit's investigational procedures. Although Phichit provided the opportunity for students to share ideas regarding the investigations, he ultimately directed students step by step of how to do the investigations. As Phichit stated, “Today we’re going to do an experiment in order to see how water changes its state . . . Students, read the experiment on the worksheet (Phichit distributes worksheets to students). Let’s see what the worksheet tells us to do . . .” (Phichit’s classroom observation #1: August, 2008).

In practice, Phichit was also a lecturer. He explained the concepts before and/or after the investigations. In the first lesson, Phichit explained the concepts after having students conduct the experiment. In the second lesson, Phichit explained the concepts after students did an investigation (observation of beads in boxes). In the last lesson, Phichit explained the concept of chemical reactions before and after the experiment.

The Role of the Student: Students are active investigators.

Phichit indicated that the role of the students in IBI was that of active investigator. To be an active investigator, students should learn science through hands-on activities. They should observe phenomena, conduct investigations, collect data, and share ideas through discussion. As Phichit explained, “In inquiry, students are the ones who conduct activities that I prepare for them. They also design learning activities. Students should be provided with an opportunity to observe and ask questions” (Phichit’s interview #1: August, 2008). In his reflection, Phichit wrote,

> The things I did in this lesson that guided students to learn were to ask questions, to give examples, and to provide opportunities for children to share ideas and conduct hands-on activities . . . the activity that is very important and I would keep in my further teaching is to have students do hands-on activities . . . (Phichit’s reflection #1: August, 2008)

However, the data showed that Phichit did not think about scientifically oriented questions[4]. He did not talk about scientifically oriented questions in the interview. In addition, Phichit did not plan to provide scientifically oriented questions for students in his lessons.

With regard to Phichit's instructional practice, the findings showed that his practice corresponded with his understanding. In practice, the student's role in Phichit's lessons was active investigator. To be active investigators, students did hands-on investigations, recorded data, and shared ideas in discussions, as illustrated in an excerpt below.

Phichit: What's going on in the test-tube?

Students: Smoke and steam.

Phichit: Students, record what you see. How about the color? What's the color of Potassium Permanganate before burning?

Students: Purple.

Phichit: What's its color after burning?

Students: Black.

Phichit: So, what's happened when you burn Potassium Permanganate?

Students: Smoke, stream, and black color. Its color is changed from purple to black.

Phichit: Now, you see? There are many changes of Potassium Permanganate in the test-tube. At first, the matter changes its form. Its color turns into what?

Students: Black.

Phichit: What else has happened?

Students: Smoke, stream, and the sound like something is breaking.

Phichit: What do you think is the reactant in this experiment?

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[4] A scientifically oriented question is a main question that students are expected to answer. This kind of question must be addressed through scientific investigation such as an experiment, survey, and reviewing information from reliable resources. The scientifically oriented question is viewed as the purpose of scientific investigation.

Students: Potassium Permanganate.

Phichit: What are the products of the reaction?

Students: Black ashes, stream, and smoke.

(Phichit's classroom observation #3: September, 2008)

However, students did not play the role of minds-on investigators. Phichit did not tell students the scientifically oriented questions. Students did not analyze data on their own. In addition, Phichit did not emphasize students to relate their proposed explanations to their prior knowledge.

Instructional Objective: Teacher aims to develop students' scientific knowledge and science process skills.

Data from lesson plans indicated that Phichit focused his lessons on scientific knowledge and science process skills. His foci were in accordance with the NSCS. With regard to scientific knowledge, Phichit wanted students to understand the concepts of heat as it affected states of matter, particles in matter, and properties of chemical reactions. As for science process skills, Phichit wanted students to practice experimentation skills.

With regard to Phichit's classroom instruction, the findings showed that his practice was compliant with his understanding. Phichit focused his teaching on scientific knowledge and science process skills consistent with the NSCS. However, for science process skills, Phichit emphasized students to practice more skills than the objectives in the lesson plans. In Phichit's teaching, students practiced several science process skills including experimentation, observation, inference, formulating hypotheses, interpretation, and making conclusions. However, the finding from both understanding and practice revealed that Phichit did not focus his lessons on scientific attitudes.

Instructional Process

Classroom Lesson Introduction: Teacher introduces the inquiry-based lesson by motivating students' interest.

Phichit believed a teacher should begin an inquiry-based lesson by motivating students' interest. Phichit thought it was important to introduce his lesson with a motivational activity. As Phichit stated, "I typically motivate students' curiosity at the beginning of my class . . . I stimulate their interests by asking questions and giving examples. Sometimes, I use games and models, and then ask questions . . . (Phichit's interview #1: August, 2008). Data from lesson plans showed that Phichit planned to motivate students' interest at the beginning of each of his three lessons. However, Phichit did not plan to link students' interest to scientifically oriented questions. He also did not think to elicit students' prior understanding of the concepts.

With regard to Phichit's teaching, the findings indicated that his practice was compliant with his understanding. Phichit motivated students' curiosity and provided the concepts of study before assigning students to conduct investigations. In his first lesson, Phichit motivated students' interest by asking them to observe and discuss water and ice. After that, he had students study the concept from the textbook. Phichit then told students a hypothesis. In his second lesson, he motivated students' interest by asking them to play with beads in a box. Phichit then discussed the observations with students. In this lesson, Phichit did not explain the concept before having students do the investigation because he already had students read this concept in the first lesson. In his third lesson, Phichit motivated students' interest by asking them to observe the burning process. He then discussed the observations with students. Phichit related that the burning process was a chemical reaction students experienced in their everyday lives. He then had students learn the concept by listening to his explanation. Thus, this finding illustrated that the investigations were used as an approach for confirming the concepts that students already knew. In addition, Phichit did not link students' curiosity to scientifically oriented questions. He did not elicit students' prior knowledge in his lessons.

Investigation: Students learn science through hands-on investigations devised by teacher, students, or both parties. However, in practice the investigations are designed only by the teacher.

Phichit thought students should acquire knowledge through hands-on investigation. He believed that students learned more when they were physically engaged in phenomena. As Phichit stated, "I think inquiry is appropriate for science teaching because it provides students opportunities to participate in hands-on activities" (Phichit's interview #1: August, 2008). The lesson plan data indicated that Phichit planned to have students conduct experiments and observe particle models of matter in three states. However, the data indicated that Phichit thought it was important to have students learn concepts from his explanation or textbook before doing an investigation.

With respect to Phichit's understanding of the one to design investigation, Phichit perceived that an investigation used in an inquiry-based lesson could be developed by the teacher, students, or both parties. As Phichit explained,

> Sometimes I ask students to design an investigation. Sometimes I prepare it for them. . . I sometimes ask students to share ideas and discuss about an investigation. I ask students questions such as, "How can we study this topic?" and "Which methods can we use for this study?" (Phichit's interview #1: August, 2008)

With regard to Phichit's teaching, the findings indicated that his practice partially complied with his understanding. In practice, Phichit had students learn science through hands-on investigations. However, all the investigations were designed by the teacher. In the first lesson, students learned the concepts of heat and states of matter by doing an experiment. In his second lesson, students learned the concept of particles of matter by observing particles' models of matter in three states. Students studied the beads in boxes as models of particles of matter in solids, liquids, and gases. In the third lesson, students studied the concept of properties of chemical reactions by doing a set of experiments including: 1) burning potassium permanganate; 2) dissolving ammonium chloride in water; 3) dissolving copper-two-sulfate in water; and 4) adding calcium into water and testing gas. Evidence of the use of investigation in Phichit's lessons is showed in his reflection below.

> In this lesson, I want students to understand properties of chemical reactions and develop experimentation skills. I think students achieved the learning objectives because they know the results of the chemical reactions. Students also conduct experiments and observe products of the reactions . . . (Phichit's reflection #3: September, 2008)

In Phichit's classroom instruction, students were assigned to follow the teacher's investigational procedures in three lessons. The written reflection data also supported this finding. As Phichit wrote, "If I have a chance to teach this concept again, I want students to engage more in discussions. I would give them the opportunity to share ideas regarding the hypothesis, experimental procedure, and the method for collecting and analyzing data. Particularly, I want students to make conclusions instead of me making it for them." (Phichit's reflection #1: August, 2008)

Conclusion/Explanation: Students should be responsible for analyzing data and formulating conclusions. However, in practice the teacher makes conclusions for students.

Phichit understood that students should be the ones who analyze data and formulate the conclusion of an investigation. However, he knew from his past experience that students could not analyze data and make conclusions on their own. He found that he had to help them by leading a discussion. As Phichit explained, "When I ask students to analyze data and make conclusions, it seems like they just give me raw data. It is not a conclusion. So I discuss with them about their data. I point out important aspects in the data and guide them to the conclusion" (Phichit's interview #1: August, 2008). The lesson plan data supported that Phichit viewed students as the ones who analyzed data and made conclusions. In his lesson plans, Phichit wanted students to analyze data and make conclusions in groups. He then had them share their conclusions with the whole class. Afterward, the whole class would discuss together in order to develop a shared understanding. After reaching a conclusion of each investigation, Phichit thought to explain science concepts relating to the investigation. The explanations aimed at guiding students toward a deeper understanding of the concepts. However, he did not think to connect the conclusion (new knowledge) with students' prior knowledge.

With regard to Phichit's teaching practice, the results indicated that his practice was not aligned with his understanding. In Phichit's teaching, students and the teacher analyzed data together. The teacher then formulated conclusion for students. Phichit helped students to analyze data by led-discussion, as illustrated in an excerpt below.

Phichit: Everybody listen to your friends' presentations and see how their data differs from your groups? So you could discuss problems or knowledge we can gain from the experiment.

Phichit: (After presentations, Phichit asks students to share ideas.) Why does the temperature decrease? Students, you help your friends to think why they have a temperature decrease. Is it consistent with our hypothesis? Our hypothesis is temperature of vapor should increase, right? But, why does this group get data like this? What are the factors that affect their data?

Students: Maybe the cover didn't close completely. There might be a hole. Vapor then is able to evaporate.

Phichit: What do you think? (Phichit asks other groups of students.)

Students: Maybe the hole is too big. So, the vapor could get out.

Students: Maybe the water dried out.

(Phichit's observation #1: August, 2008)

The finding showed that in practice Phichit provided the opportunity for students to discuss the experimental conclusions with him. However, Phichit ultimately formulated conclusions for students, as evidenced in an excerpt below.

Phichit:	What's going on in the test-tube?
Students:	Smoke and steam.
Phichit:	Students, record what you see. How about the color? What's the color of Potassium Permanganate before burning?
Students:	Purple.
Phichit:	What's its color after burning?
Students:	Black.
Phichit:	So, what's happened when you burn Potassium Permanganate?
Students:	Smoke, steam, and black color. Its color is changed from purple to black.
Phichit:	Now, you see? There are many changes of Potassium Permanganate in the test-tube. At first, the matter changes its form. Its color turns into what color?
Students:	Black.
Phichit:	What else's happened?
Students:	Smoke, steam, and a breaking sound
Phichit:	What do you think as the reactant in this experiment?
Students:	Potassium Permanganate.
Phichit:	What are the products of the reaction?
Students:	Black ashes, steam, and smoke.
Phichit:	Thus, this is a chemical reaction because the matter changes its form. The reaction produces new matter. The products of this reaction are black ashes, steam, and smoke. The properties of these products are different from their reactant.

(Phichit's classroom observation #3: September, 2008)

The above data also suggests that Phichit formulated experimental conclusions based on data gathered from the investigations. After reaching the conclusion of each investigation, Phichit connected the conclusions with related science concepts. However, he did not link the conclusions with students' prior knowledge.

Communication: Students share their data and conclusion with others; however, in practice students communicate only their data.

Phichit understood that students should share their data and conclusions with others. He viewed communication as a way students learned from each other. As Phichit stated,

> . . . I let students in my class write their data on the blackboard. Then, I ask them to present the data. I do this because I want students to see, discuss, and learn from each other. In this lesson, we find that data from one group is different from the others . . . so we discuss about the cause of this unusual data . . . some students say maybe that group put the thermometer too high, so heat transfers to the environment. The temperature of water then decreases . . . (Central meeting #1: October, 2008)

However, Phichit noted, in practice, he rarely allowed students to present data and conclusions. The teacher reasoned he did not have time. Phichit explained he typically asked students to write both data and conclusions in notebooks.

With regard to Phichit's teaching, the findings show that his practice partially complies with his understanding. In practice, Phichit provided students the opportunity to share their data with other students in class. Students communicated the data through whole class discussions, written presentations, and oral presentations. In the first lesson, Phichit assigned students to share their data via written and oral presentations. Each group of students recorded the water temperatures on the blackboard. Three groups of students then presented their data in front of the classroom, as illustrated in an excerpt below.

> Students write your data on blackboard. Group one write data under the column Group 1 . . . So, you are able to make a conclusion. Look at the hypothesis and trend of your data. . . Ok, group one send your group representative to present the data. I want you to tell the others about how you conducted the experiment, what's going on in the experiment, and what data you gained. (Phichit's classroom observation #1: August, 2008)

In the second and third lessons, students shared data via whole class discussions, as evidenced in an excerpt below.

Phichit:	Do the beads move?
Students:	Yes, they do.
Phichit:	How do they move?
Students:	They move a little bit.
Phichit:	How about the distance among the beads?
Students:	There is a tiny distance among them.
Phichit:	Could you estimate their approximate distance?
Students:	They're very close.
Phichit:	How about the beads' arrangement?
Students:	It's stable.
Phichit:	Could you draw a picture of the beads' arrangement?

(Phichit's classroom observation #2: August, 2008)

The data showed that although students had chances to share their data, they did not share their conclusions. The teacher formulated conclusions for them. As Phichit stated, "Even though I ask students to present their conclusions, they simply report their data. Students couldn't make conclusions from the data. So, I have to make it for them" (Phichit's interview #1: August, 2008). Therefore, in practice students did not have a chance to communicate, justify, and evaluate their conclusions with other alternative conclusions.

Group Work: Students learn science in groups. However, in practice, students sit in groups, but do not learn cooperatively.

Phichit perceived that in doing science students should learn together in groups. To do group work, Phichit thought all the group's members had to be involved in the group's work. As Phichit stated, "Group working requires all students in a group to be involved, observe, and do the experiments. However, for recording and analyzing data only one or two students might do. My duty is to have all students understand the concepts equally" (Phichit's interview #1: August, 2008). However, Phichit did not assign specific roles for individual group's members. The lesson plan data showed that each group contained 6-7 students of mixed-gender and ability. Phichit reasoned he mixed students because he thought it was a good strategy to promote fairness. During the interview, Phichit indicated that he grouped students by considering the number of tables available, as shown in an excerpt below.

> Because there are only six tables in the lab room, I group students by dividing the whole class into six groups. I cluster them by calling their number from one to thirty-seven. Students are then assigned to sit in six groups. For example, student number one is in group one. Student number two is in group two . . . (Phichit's interview #1: August, 2008)

With regard to Phichit's teaching practice, the finding revealed that his practice was somewhat different from his understanding. In Phichit's classroom teaching, he provided the opportunity for students to learn in groups. As described previously in his understanding, Phichit clustered students by mixed-gender and ability. He did not assign individual students roles and duties for working in groups. Phichit also did not explicitly explain or emphasize students of what they should do to have cooperative group work. Additionally, there were a high number of each groups' members (6-7 students per group). Therefore, a number of students in each group did not be on task. They sat in groups, but did not work cooperatively in groups.

Case II: Mr. Monsid

The Role of the Teacher: Teacher plays multiple roles.

The finding showed that Monsid understood that the role of the teacher in IBI was multiples. These roles include motivator, activity director, guide, facilitator and lecturer. As Monsid explained,

> In inquiry, I think the teacher should not be a main actor. The teacher should be an assistant. To take this role, the teacher should assist students in the learning. He should facilitate his students such as providing learning resources . . . To be an assistant, I motivate students' interest. The learning activities are also in my mind . . . (Monsid's interview #1: August, 2008)

During the first central meeting, the finding indicated that Monsid believed he was also a lecturer. As Monsid stated,

Researcher: What do you view the student role in this lesson?

Monsid: I think at first students have to receive knowledge from my explanation. They must gain the knowledge from me. So, the first role they played was receiver . . .

(Activity II of the first central meeting: October, 2008)

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

Monsid: Electricity is like humans. Both electricity and humans also have origins . . . Do you think all kinds of electricity have the same origin?

Students: No.

Monsid: For example, if I ask News and Palm to run to my office and bring me stuff, who should I ask for doing this job?

Students: News.

Monsid: Why?

Students: Because News is slimmer than Palm, he could run faster.

Monsid: Yes, it's like electricity. Electricity has different sources. The source of electricity affects its form. From the previous lesson, we already know static electricity. So, today we're going to do an experiment about another kind of electricity, the electricity that is in wires. Students, open your lab books on page two . . . This experiment is quite dangerous. It's the experiment of the first scientist who discovers the electricity that is in wires. The electricity we frequently use in our lives originated from this experiment. The experiment was firstly done around a hundred years ago. The first scientist who did this experiment is Alessandro Volta. So, today you're going to conduct the experiment of Alessandro Volta. Suppose that you are Volta. Students, read the experiment on page two under the title "electrochemical cell". I give you 3 minutes for reading.

(Monsid's classroom observation #1: August, 2008)

An excerpt below illustrated how Monsid guided students to do the learning activities.

Monsid: What can we use if we don't want to use copper and zinc? (Monsid reads a question in the lab book.) Oh! This question is difficult because you haven't done the experiment yet. You might not know the answer. If I tell you the answer, it's too easy. Anybody could tell me if we want to produce electricity like Volta what should we use instead of copper and zinc?

Students: Magnet.

Monsid: Hmm…iron…yes, it's possible.

Students: Wood, gold.

Monsid: I think before you answer this question, look at these (Monsid shows students copper and zinc). What are these?

Students: Metal.

Monsid: Metal (Monsid stresses). So, your answers might be correct. Zinc is metal. Copper is metal. If you want to use other materials instead of zinc and copper, you should use the material that is metal. You just said iron, it's possible. Give me 4-5 samples of metal. Then, if we have time, we might try whether they could produce electricity.

(Monsid's classroom observation #1: August, 2008)

The written reflection data also supported that in teaching Monsid played many roles. As Monsid wrote, "In this lesson, I did many things. I motivated students' interest using questions and discussions. I sequenced questions for discussion; from easy to hard. I prepared these questions ahead of time. I also advised students how to answer the questions." (Monsid's reflection #1: August, 2008).

The Role of the Student: Students are active investigators.

Monsid's response during the first interview reflected that Monsid viewed the student role as that active investigator. For Monsid, students should inquire answer of the things they were interested in. The teacher perceived that students should conduct experiments, share ideas through discussions, and make conclusions. As Monsid explained,

> I think students are detectives. To be a detective, they find the answers about things they want to know. For example, I want students to do an experiment. But, I do not assign them to do the experiment at first. Rather, I raise questions and guide them until they state the term "static electricity". I then introduce them to the experiment. It seems like students lead themselves to the experiment. (Monsid's interview #1: August, 2008)

Data from lesson plans also supported that Monsid viewed students as the ones who conduct experiments, share ideas in discussions, and make conclusions. As Monsid wrote, ". . . 5) Students conduct an experiment and answer questions on a worksheet. Students discuss data and make conclusion of the experiment in groups. 6) The whole class discuss the conclusions together in order to reach a shared understanding . . ." (Monsid's lesson plan #1: August, 2008). The written reflection data illustrated Monsid's idea that students should be interested in the topic of study. As Monsid wrote, "In this lesson, I use a demonstration of electric circuits. I think the demonstration could motivate students' interest . . . I also give examples of things related to students' daily lives (e.g., computer, power supply) because I want to have their attention . . ." (Monsid's reflection #3: September, 2008).

With regard to Monsid's teachings, the finding showed that his practice was consistent with his understanding. In practice, students were also active investigators. They conducted investigations and shared ideas in discussions. In the first and second lessons, Monsid had students conduct experiments. Students produced electricity from an electrochemical cells and dynamo. They then discussed the experimental data with others. As Monsid reflected,

> I think students achieve the learning objectives because they are interested in the learning activities. Also, students could do experiments and make electricity. They could answer my questions and the questions on worksheets. . . A thing that I will keep in this class is having students do experiments. I won't use demonstrations or dry labs. (Monsid's reflection #1: August, 2008)

In the last lesson, Monsid did not provide the opportunity for students to do a hands-on investigation. Students learned the lesson by observing demonstrations and sharing ideas in discussions, as evidenced in an excerpt below.

Monsid: When we connected 4 light bulbs with 3 batteries using the series circuit, there were only some bulbs lit. It's because the electricity was shared. According to Pim's suggestion, this time we connect 4 bulbs from the same origins. (Monsid and three students demonstrate parallel circuit.)

Students: (Students observe the demonstration.)

Monsid: Do you see? From the previous demonstration, we used 3 batteries. The 4 bulbs couldn't light. Now, we still use 3 batteries. Do the 4 bulbs light?

Students: Yes, they do.

Monsid: Why?

Students: They are connected from the same origins.

Monsid: What's going on when we connect the bulbs like this?

Students: The bulbs are equally close to the batteries.

Monsid: Yes, their distances (from the batteries) are equal.

Students: Do they get the same amount of electricity?

Monsid: Yes, they do. There is something special for connecting bulbs like this one. (Monsid disconnects one wire.) See? One bulb can't light. How about the others?

Students: They still light.

Monsid: If you observe carefully, they are brighter.

Students: Oh! Yes, they are.

(Monsid's classroom observation #3: September, 2008)

However, students did not play the role of minds-on investigators. In his three lessons, Monsid did not provide scientifically oriented questions for students and students did not analyze data on their own. He also did not have students share their conclusions in the first and second lessons. Thus students did not evaluate and justify their conclusions with alternative conclusions. In addition, Monsid did not connect the conclusions with students' prior knowledge.

Instructional Objective: Teacher aims to develop students' scientific knowledge and science process skills.

Consistent with Phichit, data from lesson plans suggested that Monsid thought a teacher should focus an inquiry-based lesson on scientific knowledge and science process skills. In his lessons, Monsid intended to have students learn scientific knowledge and science process skills consistent with the NSCS. With respect to scientific knowledge, the teacher wanted students to explain electrical charges and the motion of charges in an electromagnetic field, a process for producing direct current through an electrochemical cell, a process for producing alternating current through dynamo, principles of series and parallel circuits, and the functions of a resistor and a diode in electric circuits. For science process skills, Monsid expected students to conduct experiments regarding direct current, alternating current and to calculate resistance in series and parallel circuits.

With regard to Monsid's classroom instruction, the findings revealed that his teaching was in agreement with his understanding. In practice, Monsid also focused his inquiry-based lessons on scientific knowledge and science process skills consistent with the NSCS. However, Monsid did not aim to have students develop scientific attitudes. The written reflection data supported that Monsid focused his teaching on science content knowledge and science process skills. As he wrote,

> I think almost all of the students achieve the learning objectives. They know electrical charges and motion of charges in an electromagnetic field. Students could explain the process for producing electricity from an electrochemical cell. They could do the experiment. Thus I think students have learned both content and process skills. They also act as a scientist who discovers electricity. (Monsid's reflection #1: August, 2008)

Instructional Process

Classroom Lesson Introduction: Teacher introduces the inquiry-based lesson by motivating students' interest.

Monsid thought a teacher should introduce an inquiry-based lesson by motivating students' interest. Monsid noted he typically stimulated students' curiosity using discussion. The interview data showed that Monsid had done CAReful thinking about questions raised for discussions. He believed the questions should be related to students' everyday experiences. As Monsid explained,

> In this lesson, I use open-ended questions. The questions are related to students' experience in their daily lives. They could look around and see answers to the questions. I think questions should not ask for the meaning or principle of the concept such as what static electricity is. I think although I ask, I couldn't get the answer. I think at first I should talk about something relating to students' lives. Then, I might explain the concept. However, I won't explain the whole concept. I should stop and tell them it's something they're going to learn from the lesson . . . (Monsid's interview #1: August, 2008)

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

> The thing I did in this lesson that motivates students' interest is to tell them the history of the first scientist who produces alternating current . . . I think it's valuable for students to know the history of scientists. It's also important to let them know that they're going to do the same experiment as Faraday. (Monsid' reflection #2: August, 2008)

However, the findings showed in both understanding and practice, Mosid did not connect students' interest to scientifically oriented questions. He also did not ask students' prior knowledge in any of his lessons.

Investigation: Students learn science through experiments devised by the teacher, students or both parties. However, in practice the investigations are designed only by the teacher.

Monsid believed that experimenting was the only approach appropriate for students to learn science. He thought reviewing information from learning resources was not a useful approach for studying science in IBI. As Monsid explained,

> I think inquiry teaching is not only to have students do a report. Like some teachers do, they give students a topic, have them search information from the Web, and write a report. I think it's not inquiry teaching. It's only a suggestion, if the teacher asks students to review content from learning resources and write a report, for me, this is a teacher's product. That teacher wants to get a promotion (e.g., from school district). Someone might say it's their inquiry teaching. But, for me, it's not. Having students conduct an experiment is inquiry. This is my view of inquiry. (Monsid's interview #1: August, 2008)

The lesson plan and written reflection data also supported Monsid's conception that experimentation was the only way for learning science in IBI. In his first and second lessons, Monsid wanted students to do experiments. In the last lesson, he planned to have them observe demonstrations. However, Monsid reflected he did not want students to observe demonstrations. He wanted them to do an experiment. As Monsid wrote, "The thing that I want to refine in this lesson is the demonstration. I want students to do an experiment rather than to observe the demonstration. However, I could not have them do this because I do not have enough materials" (Monsid's reflection #3: September, 2008).

With respect to Monsid's understanding of the one to design the investigation, he understood that an experiment could be developed by the teacher or students. Monsid thought it was dependent on the science concept. As Monsid stated,

> I think it (the person who designs the investigation) is dependent on the science concept. If students study a concept that is related to their everyday lives or they used to learn the concept before, I might have them design the experiment. Conversely, if they learn a concept that isn't found in their everyday experiences or they don't know about the concept before, I couldn't let them plan the experiment. (Monsid's interview #1: August, 2008)

With regard to Monsid's teaching, the results showed that Monsid's practice was somewhat consistent with his understanding. In practice, Monsid had students engaged in hands-on activities in some lessons. In the first and second lessons, students conducted experiments. In the third lesson, students observed demonstrations and shared ideas in discussions. As Monsid reflected, "I teach electric circuits using demonstrations. I show students how to connect the circuits. Students observe and discuss with me. I also show them real electrical parts such as diode and mother circuit board" (Monsid's reflection #3: September, 2008). However, both experiment and demonstration were devised by the teacher. Monsid did not ask students to share ideas regarding the design of the investigations.

Conclusion/Explanation: Students are responsible for analyzing data and formulating conclusions.

Monsid understood that students should be responsible for analyzing data and formulating conclusions. However, Monsid knew from his past experience that it was difficult for students to analyze data and make conclusions on their own. As Monsid stated, "I think my students are weak in this point. Although I have them analyze data and formulate conclusions, students couldn't make conclusions as I expected. So I assist them by leading discussions. The discussions are aimed to guide students to conclusions" (Monsid's interview #1: August, 2008). The lesson plan data supported Monsid's view that he thought students were responsible for analyzing data and formulating conclusions. As Monsid wrote,

> . . . 4) Students conduct experiments and answer questions on worksheets. Students discuss the data and make a conclusion from their data in groups. 5) The whole class discusses together in order to develop a shared understanding. 6) The teacher explains concepts regarding sources and types of electricity . . . (Monsid's lesson plan #2: August, 2008)

The above data also provides evidence that Monsid believed he should link conclusions to science concepts. However, no data indicated that Monsid thought to connect the conclusions (new knowledge) to students' prior knowledge.

With regard to Monsid's classroom instruction, the results reveal that his practice coincided with his understanding. In practice, both Monsid and his students analyzed data. Students made conclusions on their own in the first and second lessons. In the third lesson, Monsid and his students formulated the conclusion together. In Monsid's teachings, the teacher and students analyzed data together through led-discussions, as illustrated below.

Monsid:	You said it's probably because the circuit may not have enough energy. So, this time I'll use new batteries. (Monsid connects new batteries into the circuit.)
Students:	(Students observe the demonstration.)
Monsid:	Same results!? It's only two bulbs light. What do you think?
Students:	The wire is too long. Electricity couldn't transfer to the bulbs.
Monsid:	Observe the two bulbs carefully. Do they bright equally?
Students:	Yes/No/Not sure.
Monsid:	Ok, I'll use 6 batteries. It might provide a clear result. What do you think would happen?
Students:	The two bulbs will have more brightness.
Students:	The four bulbs will be lighted.

Monsid:	(Monsid connects the circuit with 6 batteries.) You see?
Students:	Oh! All bulbs are lit. But, it's odd.
Students:	Their brightness is not equal.
Monsid:	Yes, which one is the brightest?
Students:	The one that is close to Nikorn.
Monsid:	Do you know why?
Students:	Not sure/Don't know.
Monsid:	One of your previous answers is correct.
Students:	The wire is too long?
Monsid:	Yes, all bulbs need electricity. Nikorn, do you know what charge of the batteries is close to you?
Nikorn:	Cathode?
Monsid:	Yes, it is. The brightest bulb is the one that is close to the cathode. It's because the four bulbs want electricity. But electricity moves from cathode to anode. So, the first bulb close to cathode gets more electricity than the others . . . As for your answer, there is not enough energy to light them. Scientists name this kind of circuit a "series circuit" If I disconnect one bulb, what do you think would happen?
Students:	The others won't light.
Monsid:	(Monsid disconnects one bulb in the circuit.) Yes, all of the bulbs can't light. They need each other. However, the bulb that is close to cathode gets more energy than the others.

(Monsid's classroom observation #3: September, 2008)

The above data also showed that the conclusion was formulated based on data obtained from teacher-led investigation. In the first and second lessons, Monsid did not allow students to share their conclusions with others. Students were assigned to write conclusions in lab books. Therefore students did not have a chance to evaluate and justify their conclusions with alternative explanations in these lessons. After reaching the conclusion of each investigation, Monsid explained science concepts relating to the investigations. However, he did not connect the conclusions with students' prior knowledge.

Communication: Students share data and conclusions with others; however, in practice students communicate only their data.

Monsid knew that students should share their data and conclusions with others. Monsid noted he typically had students communicate data and conclusions via whole class discussions. However, the teacher commented in practice he occasionally allowed students to share their conclusions. As Monsid explained,

> Nowadays I don't have time. It isn't the same as in the past. In the past, I asked students to share data and conclusions. But given the time I have, I couldn't let them do this. I only ask them to hand in their work. Thus students share their conclusions with me. But they don't share it with their classmates. I want students to do so, but I don't have time. (Monsid's interview #1: August, 2008)

With regard to Monsid's classroom instruction, the finding revealed that his teaching partly agreed with his understanding. In Monsid's teaching practice, he provided students with the opportunity to communicate their data with other students. However, he did not have them share their conclusions in two of the lessons. Students wrote their conclusions in lab books, as evidenced in an excerpt below.

Monsid:	Students, I want you to work in groups to write an experimental conclusion in your lab book. The same group should have the same conclusion. Ok, I'll give you 1 minute to write the conclusion.
Students	(Each groups of students write the conclusion.)
Monsid	Times up! Look at the blackboard. Open your book to next page. Can you see the word "electrochemical cell"?
Students	Yes.

Monsid According to this word, it contains a word “chemical”. What does this word referring to?

Students: New product?

(Monsid’s classroom observation #1: August, 2008)

Group Work: Students should learn science as individuals. However, in practice, students also learn both individually and in groups.

Monsid thought students were better able to learn individually. He believed students could reach a comprehensive understanding of science concepts when they learned in isolation. He did not agree with the idea that students should learn science in groups. Monsid thought students had less competition when they learned in groups and for him competition was a key factor for science learning. As Monsid explained,

> To learn in groups, students couldn’t get 100% of the knowledge. It might be only one or two students who have a deep understanding . . . For me, students gain more knowledge when they learn individually. I think individual learning supports competition . . . In group work, students also have competition. But, it’s less than individual learning . . . I believe even if I assign students lots of work. There is still someone who doesn’t help the others. If you ask me if it’s necessary for students to work in groups, I would say “yes”. But I don’t think it works. (Monsid’s interview #1: August, 2008)

The data found that Monsid thought that in science learning students sometimes had to learn in groups. The teacher indicated materials and cost for producing product were his main factors to have students work in groups, as evidenced in an excerpt below.

> In science teaching and learning, I sometimes have students work in groups. It’s because I don’t have enough materials. If I had more materials, I’d let students do experiments individually. I think it is better for them to understand

> concepts . . . number of group member depends on the situation. For example, in electricity, students have to invent something. They must buy materials. Thus a group might consist of 10 students. I couldn’t have a few members because I don’t want them to spend a lot of money. (Monsid’s interview #1: August, 2008)

The above data also suggested that Monsid had students work in groups because he was concerned about materials and cost for producing product rather than students’ learning through the social interaction during group work.

With regard to Monsid’s teaching practice, the finding revealed that his practice was somewhat different from his understanding. In practice, Monsid had students learn both in groups and individuals. In the first and second lessons, students learned science in groups. They conducted experiments, answered questions in their lab books, and formulated conclusions. There were 5-8 students per group. In the last lesson, students learned individually. They observed demonstrations and shared ideas in discussions. These findings aligned with Monsid’s understanding in that he thought students should learn in groups only when they do experiments. For Monsid, student groups were only needed to share experimental equipment. In his teaching, Monsid did not assign individual students roles during group work or provide guidance on how to work cooperatively in groups. Additionally, there were a high number of students in each group.

Case III: Mr. Suriya

The Role of the Teacher: Teacher should be a guide and a facilitator; however, in practice teacher plays multiple roles.

Suriya’s respond during the first interview indicated that he believed the teacher role was that of guide and facilitator. As Suriya stated, “I think the teacher’s role is an advisor. The teacher helps students to achieve the learning goal which it is to understand science concepts. I think my role is to advise and assist students to accomplish this goal" (Suriya's interview#1: August, 2008).

In terms of teaching classroom instruction, Suriya's practice did not agree with his understanding. Practically, Suriya played multiple roles in his lessons. These roles included activity director, motivator, guide, facilitator, and lecturer. In the three lessons, Suriya designed learning activities, motivated students' interest, guided students in how to do the activities, prepared learning materials, and explained the concepts. His role as activity director and facilitator is evident below.

Suriya: Now, I want you to design an experiment. We have five steps for doing an experiment. What is the first step?

Students: (Silent.)

Suriya: The first step, you have to define what?

Students: Question.

Suriya: What is the second step?

Students: Stating a hypothesis.

Suriya: Yes, stating hypothesis. What about the third step?

Students: (Silent).

Suriya: Why don't you read your worksheets? You couldn't answer me even though the answers are on worksheets. Could you tell me what topic you are going to experiment?

Students: Orbit of the planets.

Suriya: Excellent! Now, you could answer exactly the same as it appears on the worksheet.

(Suriya's classroom observation #1, August, 2008)

The teacher's role as guide is illustrated in the excerpt below.

Suriya: What is the hypothesis of this experiment? The hypothesis should be something related to the orbit of the planets or rapidity of the planets' orbit. What does the planet orbit around?

Students: The sun.

Suriya: Do the 8 planets spend equal time to orbit around the Sun?

Students: No.

Suriya: The problem is "we don't know". So, the hypothesis should be?

Students: How long the planets orbit around the sun?

Suriya: It should be something about time.

Students: Do the planets spend equal time to orbit around the Sun?

Suriya: If you use that sentence, it's not a hypothesis. It's a question. If you want to formulate hypothesis, you must point out a direction of the result that you think would happen. So, what should you say?

Students: The planets spend unequal time to orbit around the Sun.

Suriya: Yes, but if you want to say they spend equal time, is it ok?

Students: Yes, it is.

Suriya: Yes, it could be equal or unequal. It's dependent on your groups. You choose which one you want to use. So, everyone doesn't have to use the same hypothesis.

(Suriya's classroom observation #1, August, 2008)

The classroom observation data also indicated that Suriya played a role of lecturer. In the first lesson, he explained the concept of gravitational force before having students do as experiment. In the other two lessons, Suriya reviewed concepts of previous lessons and explained the concepts of the current lesson before having students conduct an investigation.

The Role of the Student: Students are active and minds-on investigators.

Suriya believed that the role of the student in IBI was that of active and minds-on investigator. As Suriya responded, Researcher: What do you think of is the student's role in inquiry-based lessons?

Suriya: I think students should play a role of enthusiast. They should be curious about things they study. I try to motivate their curiosity. But, they don't want to know anything, particular in science.

Researcher: Besides enthusiast, what are other roles students should play?

Suriya: They must seek the answer of things they want to know. They might do experiments or search for information. It's dependent on the concept.

(Suriya's interview#1: August, 2008)

The lesson plan data suggested that Suriya thought students should also share ideas in discussions, pose experimental questions (scientifically oriented questions), formulate hypotheses, conduct experiments, analyze data, make conclusions, and write reports.

With regard to Suriya's classroom practice, the finding indicated that his practice was not in agreement with his understanding. In Suriya's teaching, students were passive investigators. They occasionally shared ideas in discussions. In the three lessons, Suriya provided opportunities for students to raise scientifically oriented questions, formulate hypotheses, design investigations, analyze data and formulated conclusion. However, only some students shared their thoughts. The majority of students waited for the teacher to answer his questions. However, the students did investigations as Suriya directed them to. The role of students as passive investigators is illustrated in an excerpt below.

Suriya: How should we conduct the experiment? The first step, what is the problem? (Suriya points out each group of students.)

Group 1: Where does gravity come from?

Suriya: Ok, where does gravity come from? (Suriya points out Group 2.)

Group 2: What is the origin of gravity?

Suriya: What is the origin of gravity? What else?

Group 3: How is gravity related to the object?

Suriya: How is gravity related to the object? Students, jot down the questions on your worksheet. We already discussed 2-3 questions. Some students still keep quiet. What else is a problem?

Students: (Silent.)

Suriya: How about groups that didn't answer? What do you think as a problem?

Students: (Silent.)

Suriya: Any group that has questions that you want to answer?

Students: (Silent.)

Suriya: Ok, we have only three questions. Where does gravity come from? What is the origin of the gravity? And, how is gravity related to the object? These questions are similar. It's easy to build up a question. You just add a question word into a sentence. The question provides a goal that we want to achieve. Ok, how about the last two groups? Do you have any questions to share?

Students: (Silent.)

Suriya: Ok, you don't have any. Students, look at the questions we have. The main question is why don't objects on the Earth away from the Earth?

(Suriya's classroom observation #2, September, 2008)

Instructional Objective: Teacher aims to develop students' scientific knowledge and science process skills.

Similar with Phichit and Monsid, the lesson plan data showed that Suriya thought science teaching through IBI should focus on scientific knowledge and science process skills. In his lesson plans, Suriya emphasized scientific knowledge and science process skills in accordance with the NSCS. With respect to scientific knowledge, Suriya expected students to understand the concepts of planets in the solar system, gravitational force, linear motion of objects, and forces that affect linear motion of objects. For science process skills, he wanted students to analyze data (regarding planets in the solar system) gathered from worksheets and to conduct experiments about gravitational force and linear motion of objects. He also wanted them to write experimental reports.

With regard to Suriya's teaching, the finding indicated that his classroom instruction was aligned with his understanding. In practice, Suriya emphasized his lessons on scientific knowledge and science process skills consistent with the NSCS. For science process skills, like Phichit, Suriya had students practice more skills than he wrote in his lesson plans. Students practiced several skills including formulating hypotheses, experimentation, interpretation, and making conclusions. However, he did not emphasize that students need to develop scientific attitudes.

Instructional Process

Classroom Lesson Introduction: Teacher introduces the inquiry-based lesson by motivating students' interest and clarifying the main question.

Similar to Phichit and Monsid, Suriya believed that he should motivate students' interest at the beginning of an inquiry-based lesson. As Suriya stated,

Researcher: Could you tell me what the science teacher should do for introducing an inquiry-based lesson?

Suriya: I'm not sure about the others. But, for me, I have used many activities for introducing my lessons. I sometimes provide students examples or have them play games. I also narrate stories or have students observe demonstrations.

Researcher: What do the activities aim for?

Suriya: It aims to motivate students' interest and to have them know what they're going to study.

(Suriya's interview#1: August, 2008)

The lesson plan data supported Suriya's notion in that he thought the teacher should introduce an inquiry-based lesson by motivating students' interest. In the first lesson plan, Suriya thought to stimulate students' curiosity using discussion regarding planets in the solar system. In the second lesson, he planned to have students drop objects on the floor and then discuss with them about why the objects fall. In the last lesson, he wanted students to observe a demonstration of a linear motion and then discuss the demonstration with them. The lesson plan data also reflected Suriya's conception in that he thought it was important to link students' interest to a scientifically oriented question. Suriya planned to have students pose experimental questions in his three lessons.

With regard to Suriya's classroom instruction, the results showed that his teaching partly agreed with his understanding. In practice, Suriya introduced his inquiry-based lessons by motivating students' interest, clarifying the main question and/or providing the concepts of study. In the first lesson, he began the lesson through a motivational activity. Suriya had students match pictures and names of the planets in the solar system. He and his students then discussed the planets' names (both the Thai names and English names) and sequence of the planets from close to far from the Sun. In the second lesson, Suriya started his lesson by having students drop an object and discussed gravitational force with them. In his third lesson, the teacher introduced his lesson by having students observe liner motion of an object and then discussed the observation with students. After that, Suriya reviewed the concepts of gravitational force, formula for calculating gravitational force between two objects, weight, mass, and linear motion of objects. Thus, in his three lessons, Suriya explained the concepts before having students conduct investigations. After providing the concepts of study, Suriya inform students the question to investigate. However, the finding showed that Suriya did not elicit students' prior knowledge in his three lessons. In addition, it seemed like the discussions could not motivate their interest, as illustrated in an excerpt below.

Suriya: Students, could you drop an object on the floor?

Students: (Students drop an object.)

Suriya: What's going on?

Students: It fell.

Suriya: Absolutely. Why does it fall?

Students: Because of gravity.

Suriya: Because of gravity. If the Earth does not have gravity, we would soar into the air. Could you tell me what is gravity?

Students: (Silent.)

Suriya: You can call the name. Excellent! But, can you tell me what is gravity?

Students: (Silent.)

Suriya: Guess, what is gravity?

Students: (Silent.)

Suriya: Ok, you can't answer. You just drop an object on the floor, right? The object can't soar into the air. It means that there is a force between the object and the Earth, right?

Students: Yes.

Suriya: Do you think this force is a pushes or pulls on the object?

Students: Pulls.

Suriya: Yes, it pulls the object. If it pushes, the object should bounce off. From what we saw, the object fell on the ground. So, every object on the Earth is pulled into the Earth's core. This force or what you call "gravity" pulls the object. Do you know where gravitational force comes from?

Students: (Silent.)

Suriya: Gravitational force is a force between an object and the Earth. If we experience this force on the Earth, we call gravity of?

Students: The Earth.

Suriya: Do you think there is this kind of force on the Moon?

Students: Yes, it is.

Suriya: Yes, the Moon also has its gravity. How's about Mars? The planet Mars also has its gravity. The fact is all objects in our solar system have gravitational force among each other. If they

> didn’t have this force, the sun would stay alone. It couldn’t be a solar system . . .
>
> (Suriya’s classroom observation #2, September, 2008)

The above data showed that many questions Suriya used in discussions asked about facts and definitions of science concepts. This kind of questioning may impede students’ participation in discussion because to have the right answers students needed to remember the definition of scientific terms.

Investigation: Students should design and conduct investigations; however, in practice the investigation are designed only by the teacher.

Suriya understood that students should be the ones who design and conduct investigations. However, the teacher knew in practice students could not design investigations. Suriya commented that he must direct the steps of investigations for students. As Suriya stated, “In fact, I want students to design investigations. But, from my experience students couldn’t do this. Thus investigations are entirely from my ideas.” (Suriya’s interview#1: August, 2008). For Suriya, scientific investigations used in IBI were designed by following the steps of the scientific method. As Suriya explained, “The inquiry process is a process that covers the scientific method, which includes stating a problem, formulating a hypothesis, collecting data for testing the hypothesis, discussing data, and making a conclusion” (Suriya’s interview#1: August, 2008). The lesson plan data also supported this conception. In his three lesson plans, Suriya developed the investigations by covering steps of the scientific method. He planned to have students review data from worksheets and conduct experiments. However, Suriya thought reviewing information from learning resources was a sort of experiment. As he explained,

> . . . Sometimes, I have students do experiments. In some lessons, I ask them to search for information from the textbook or Web and then write a report. It’s dependent on the content. However, I try to have students understand that although they review information from a textbook or the Web, it’s also an

> experiment. In the past, students thought reviewing information wasn't an experiment. Experiment referred only to an activity that requires students to mix chemical substances or use fire. At present, I'm trying to change their understanding of experiments. I want students to know that even when they review information, it's also an experiment. The importance is to have students know what a problem is and how to answer the problem. (Suriya's interview #1: August, 2008)

In addition, the lesson plan data showed that Suriya thought it was important to discuss or have students read about the concept of study before doing investigations.

With regard to Suriya's classroom teaching, the finding indicated that his practice was partially aligned with his understanding. In his instruction, Suriya had students do experiments and review information from worksheets. However, all of the investigations were designed by the teacher. In the first lesson, students addressed a scientifically oriented question by reviewing information from a worksheet, as evidenced in an excerpt below.

Suriya:	What is the third step?
Students:	(Silent.)
Suriya:	Quickly, what is the third step?
Students:	Do the experiment.
Suriya:	How? Could you read (the worksheet) how to do the experiment?
Students:	(Students read the experiment on the worksheet out loud.) Learners conduct experiment and record data in order to test hypothesis. . .
Suriya:	In the experiment today, you don't mix any substances or connect a circuit. But, you just read information on worksheets, analyze the information, and write me a report. If you plan and do the work step by step, it's also an experiment.

(Suriya's classroom observation #1, August, 2008)

The above data supported Suriya's understanding in that he thought reviewing information about an experiment from a learning resource was a sort of experiment. In the second and third lessons, students did real experiments. In his three lessons, students did investigations (both real experiment and reviewing information) by following the steps of the scientific method. In practice, he provided students the opportunity to share ideas regarding investigational procedure. However, only some students communicated their thoughts. Therefore, Suriya ultimately told students to follow his investigational procedures, as evidenced in an excerpt below.

Suriya:	Linear motion and vertical motion are related. We'll do an experiment in order to answer how they are related. How should we design the experiment?
Students:	(Silent.)
Suriya:	We already knew that an object could move because of force. I will give you this equipment (a rubber band, a wooden arrow, and a shooting board). Could you plan how to do the experiment?
Students:	(Silent.)
Suriya:	Does the arrow move if we don't have shooting equipment?
Students:	No, it couldn't move.
Suriya:	What could we use as a shooting device?
Students:	Rubber band.
Suriya:	Yes, you could use a rubber band for shooting. If you put a shooting board on a plain area, how does the arrow move?
Students:	It'll go straight.
Suriya:	What would happen if we put a shooting board on a table? Does the arrow move horizontally?
Students:	(Silent.)
Suriya:	Ok, students read the experiment on the worksheet and then conduct the experiment.

(Suriya's classroom observation #3, September, 2008)

Conclusion/Explanation: Students should be responsible for analyzing data and formulating conclusions.

Suriya perceived that students should be the ones who analyzed data and made conclusions. However, the teacher commented that in practice it was difficult for students to do so. He assisted students by discussing data and conclusions with them. As Suriya explained,

> In fact, I want students to make conclusions. However, I haven't seen students make conclusions using their words. I always have to help them. We (the teacher and students) analyze data and answer question (make conclusions) through whole class discussion. Students write what we discuss on their reports. However, their written conclusions still don't reach my expectation. I think 9th grade students could make conclusions better than what they do. (Suriya's interview #1: August, 2008)

The lesson plan data also supported that students should be responsible for analyzing data and making conclusions. In his lesson plans, Suriya wanted students to analyze data and make conclusions. After reaching a conclusion of each investigation, Suriya planned to connect the conclusions to the science concept. However, he did not think to link the conclusions with students' prior knowledge.

With regard to Suriya's teaching practice, the findings showed that his practice was not in agreement with his understanding. In practice, Suriya and students analyzed data and made conclusions together in two lessons whereas students analyzed data and made conclusion on their own in one lesson. An excerpt below illustrates how Suriya analyzed data and formulated a conclusion with students.

Suriya: Now, we're going to do the forth step. What is it?
Students: Analyze data.

Suriya: Yes. You must analyze data in order to see whether the result agreed with the hypothesis. So, what do the 8 planets orbit around?

Students: The sun.

Suriya: What is a characteristic of their orbit?

Student: Circle/oval.

Suriya: The majority of them orbit in?

Students: Oval.

Suriya: Yes, most of the planets have an oval orbit. How about their orbital plane?

Students: They orbit in the same plane.

Suriya: How are their distances from the sun?

Students: Their distances are different.

Suriya: Which one is the closest?

Students: Mercury.

Suriya: How does its closeness to the Sun compare with the Earth?

Students: . . .

Suriya: . . .

Suriya: We already analyzed data. So, you should record what we found on your worksheets. What's the last step? What is the fifth step?

Students: Make conclusion.

Suriya: The last step is when you make a conclusion. You should make a conclusion by answering what?

Students: Hypothesis.

Suriya: What's your hypothesis?

Students: The 8 planets spend equal time to orbit around the Sun.

Suriya: Yes, it's dependent on your hypothesis. You must follow your hypothesis. But, the important thing is you have to include information about the time each planet uses to orbit around the Sun.

(Suriya's classroom observation #1, August, 2008)

In the third lesson, students were assigned to write data and conclusions on worksheets. They did not share their data and conclusions with others. Students did not discuss together to reach a shared understanding of the conclusion. After concluding each investigation, Suriya did not connect the conclusions with either science concepts or students' prior knowledge. He ended his lessons by having students write reports.

Communication: Students share data and conclusions with others.

Suriya understood that students should share their data and conclusions with other students. As he stated, "In inquiry teaching, I have students share data and ideas regarding conclusions through discussion. But, I don't have them present their work in front of the classroom" (Suriya's interview #1: August, 2008). The lesson plan data also supported his notion that students should share data and conclusions. In the lesson plans, Suriya wanted students to analyze data and make conclusions through whole class discussion. He then had them write conclusions on worksheets.

With regard to Suriya's teaching practice, the result indicated that his practice was in agreement with his understanding. In his teaching, Suriya provided the opportunity for students to communicate their data and conclusions in the first and second lessons. He did not have students share data and conclusions in the last lesson. Although Suriya gave students chances to communicate their data and conclusions, there were only some students who joined the discussions. As Suriya reflected, ". . . in practice, many students do not share ideas in discussions. They just listen to the discussions. So, I have to activate them to communicate their thinking" (Suriya's reflection #1: August, 2008). In the third lesson, Suriya had students write data and conclusions on worksheets. Therefore, students did not have a chance to communicate, justify, and evaluate their conclusions with alternative conclusions.

Group Work: Students should learn science in groups. However, in practice, students sit in groups, but do not work cooperatively.

Suriya knew that students should learn science in groups. To learn in groups, Suriya thought students should help each others and play their roles in completing the task. As he stated,

Researcher: Why do you reduce the number of a group's members (from 8 to 3 students)?

Suriya: Because I want students to have more responsibility on their work. I want all students to be part of their group's work. I knew that when a group had 7-8 members, only some students did the work.

(Suriya's interview #1: August, 2008)

To do group work, Suriya also thought each individual should have a specific duty. The lesson plan data showed that the specific duties included: 1) receiving and returning learning materials, 2) reading activities on the worksheet, 3) recording data, 4) making conclusions, 5) and answering questions on the worksheet (including conclusion).

With regard to Suriya's classroom instruction, the finding indicated that his practice was not compliant with his understanding. In practice, students sat in groups but they did not work cooperatively. In his three lessons, Suriya had students learn in groups. Students sat in groups of 4-5 members. Suriya provided specific roles and duties for individual group members, as illustrated below.

Suriya: Students, let's locate yourself in groups. What would you do next? Forget again!? Why do I have to tell you every time? What should you do first?

Students: Select the head.

Suriya: Yes. After that, you should do what?

Students: Assign each member a role and duty.

Suriya: Yes. Assign individual members roles and duties. Ok, Member no. 2 of each group, come here to get learning material.

(Suriya's classroom observation #1, August, 2008)

However, in practice, many students did not play their roles and duties in groups. Around 2-3 groups of students did not participate in learning activities. They did something unrelated to the lessons such as reading a comic book, writing in a friendship books, and doing homework for other classes. In his three lessons, although Suriya had students sit in small groups, the teacher had them work in large groups for doing investigations. As Suriya stated, "I want four groups to work together because I have only two sets of equipment. Actually, I have six sets, but I don't know where they are now. Ok, students who sit on this side are in one group. The rest are in another group" (Suriya's classroom observation #2: September, 2008). In the last lesson, Suriya also had students learn in large groups. As he stated, "Now, it's time for you to do the experiment. Two groups will work together. Students, combine two groups into one group. Reorganize your tables. Two groups work inside this room while the others experiment outside the room" (Suriya's classroom observation #3: September, 2008).

Common Findings

The Role of the Teacher: Teacher is a guide and a motivator.

The findings from the three teachers showed that all of three teachers consistently agreed that the role of the teacher in IBI was that of guide and motivator. However, their practice was different. Specifically, Phichit understood that the teacher role in IBI was that of guide and motivator. However, in practice, besides a guide and a motivator, Phichit was also an activity director and a lecturer. For Suriya, like Phichit, he thought the role of the teacher included guide and facilitator; however, in practice, he played multiple roles in his lessons. These roles included activity director, guide, motivator, facilitator, and lecturer. In the case of Monsid, his classroom instruction was in agreement with his understanding. Monsid believed the role of the teacher was multiples. These were motivator, activity director, guide, facilitator and lecturer.

The Role of the Student: Students are active investigators.

The findings from the three teachers revealed that all the teachers understood that the role of the students was active investigator. However, there was a variety of teaching practice among the three teachers. Phichit's and Monsid's classroom instruction was aligned with their understanding. Both teachers viewed the student role as active investigator. However, they did not conceive the idea that the role of the student was minds-on investigator. For Suriya, he understood that the student's role was that of active and minds-on investigator. Conversely with his understanding, in practice his students played the role of passive investigator.

Instructional Objective: Teacher aims to develop students' scientific knowledge and science process skills.

The findings across the three case study teachers showed that the teachers consistently accepted that they should emphasize their inquiry-based lessons on scientific knowledge and science process skills in accordance with the NSCS. All the teachers' practice was consistent with their understanding. However, the three teachers did not focus their lessons on scientific attitudes.

Instructional Process

Classroom Lesson Introduction: Teacher introduces the inquiry-based lesson by motivating students' interest.

The findings from the three teachers showed that all three teachers knew that they should introduce an inquiry-based lesson by motivating students' interest. However, the teachers' practice was variety. For Phichit, he introduced his inquiry-based lessons by motivating students' interest as well as proving students the concepts of study. Similar to Phichit, Suriya introduced his lessons by motivating students' interest, telling students the concept of study and clarifying the main question to investigate. For Monsid, his teaching was in agreement with his understanding. He introduced his lessons by motivating students' interest. However, the three teachers did not elicit students' prior knowledge of the concepts being studied. Additionally, both Phichit and Monsid did not understand that they should link students' interest to scientifically oriented question.

Investigation: Students learn science through hands-on investigations.

The findings from the three case study teachers showed that all three teachers understood that in IBI students should learn science through hands-on investigations. However, the teachers held different notion regarding the one to design the investigations. For Phichit, he believed the investigation could be developed by the teacher, students, or both parties. Similar with Phichit, Monsid thought the investigation (experiment only) could be designed by the teacher or students. For Suriya, he believed students should be responsible for designing the investigation. In addition, the three teachers consistently agreed that they should provide students scientific knowledge before allowing them to conduct the investigation. With regard to the teachers' teaching practice, the findings indicated that there was somewhat inconsistent between the teachers' practice and understanding. The three teachers had students learn science through hands-on investigations; but, the investigations were devised only by the teacher.

Conclusions/Explanation: Students are responsible for analyzing data and formulating conclusions.

The findings across the three case study teachers indicated that all of the teachers conceived that in IBI students should be responsible for analyzing data and formulating conclusions. After reaching a conclusion of each investigation, Phichit and Monsid thought they needed to review concepts. The explanation was aimed to help students to have a deeper understanding of concepts. For Suriya, he did not plan to review the science concepts. Rather, Suriya wanted students to write experimental reports. The findings showed that none of the teachers thought to make a connection between the conclusion (new knowledge) and students' prior knowledge.

With regard to the teachers' teaching practice, the findings revealed that there was some inconsistency between the teachers' practice and understanding. In practice, Phichit and students analyzed the data together. After that, Phichit formulated conclusions for students. For Monsid, he and his students analyzed data together. Monsid then had students make a conclusion on their own in two lessons. He and students formulated a conclusion together in one lesson. In the case of Suriya, he and his students analyzed data and made conclusions together in two lessons. Suriya had students analyze data and formulate conclusions by themselves in one lesson.

Communication: Students share their data and conclusions with others.

The findings from the three teachers showed that all of the teachers consistently perceived that students should share their data and conclusions with other students in class. However, the three teachers' teaching practice was somewhat different from their understanding. For Phichit, students had chances to share their data with others. However, they did not communicate their conclusions. Like Phichit, Monsid had students communicate their data with other groups of students. However, they did not share their conclusions in two of the lessons. For Suriya, students had chances to communicate their data and conclusions in two lessons. They wrote data and conclusions on worksheets in the third lesson. Therefore, there were some lessons that students did not have opportunities to justify and evaluate their conclusions with alternative conclusions.

Group Work: Students learn science in groups or as individuals.

The results from the three case studies indicated that Phichit and Suriya agreed that students should learn science in groups whereas Monsid believed they should learn science as individuals. For Phichit and Suriya, to do group work was to have all the group's members be involved in the work of their group. Suriya also stressed that students should play their roles in completing the task. In the case of Monsid, he did not perceive that students could learn more when they studied in groups.

With regard to the teachers' teaching practice, their practice was somewhat inconsistent with their understanding. In Phichit's and Suriya's classroom instruction, students sat in groups, but did not work cooperatively in groups. There were a high number of students in a group. Many members in a group might impact students' effectiveness in terms of learning outcomes. In addition, Phichit did not provide individuals specific roles and guidelines for working cooperatively in groups. For Monsid, he had students learn both in groups and individually. Like Phicht, Monsid did not provide individual roles and guidelines for cooperative group work. He also had students learn in large groups.

Discussions in Relation to the First Research Question

The discussions of the teachers' understandings and practices about particular aspects of the essential features of IBI are provided below.

Role of the Teacher and Role of the Students

For the role of the teacher, Phichit, Monsid, and Suriya consistently agreed that the roles of the teacher in an inquiry-based classroom were that of guide and motivator. This understanding partially agrees with Dewey (1938 cited in Barrow, 2006: 266) who believed the science teacher should play the roles of guide and facilitator. Additionally, Monsid and Suriya perceived that the teacher's role was also activity director. The two teachers indicated science teachers should design learning activities for students. This notion complies with the NSCS (DCID, 2002). According to the NSCS, science teachers should decrease the role of lecturer. Teachers should take the role of planner, the one who designs learning activities that helps students learn science through the inquiry process. This finding was somewhat compliant with the study of Ketsing and Roadrangka (2008) in which they found that some science teachers (32.4%) in schools participating in the EOLS Project viewed their role in IBI as facilitator, guide and motivator.

In terms of the role of the student, the three teachers viewed the student's role as active investigator. The teachers understood that students should learn science through hands-on investigations. They should conduct investigations, analyze data, make conclusions, and share their thoughts with others. This understanding was somewhat consistent with the NSCS (DCID, 2002). According to the NSCS (DCID, 2002), the inquiry process is a process that lead learners to construct knowledge through several activities such as observing phenomena, stating a question, and doing a scientific investigation. Most importantly, learners must be involved in all learning activities, starting from the planning of the activity to assessing their own learning. The teachers' notion regarding the student's role also complies with the NSES (National Research Council, 1996). According to the NSES (National Research Council, 1996: 20), "In learning science, students describe objects and events, ask questions, acquire knowledge, construct explanations of natural phenomena, test those explanations in many different ways, and communicate their ideas to others." The findings also agreed with the study of Ketsing and Roadrangka (2008) in which they found that the majority of science teachers (91.2%) in schools participating in the EOLS Project understood that in inquiry teaching, students should play an active role in constructing their own knowledge.

However, Phichit's and Monsid's concepts regarding the student's role is not in agreement with the idea that the student's role is of minds-on investigator. In these cases, the two teachers did not consider the significance of the prior knowledge that students bring into the science classroom. Phichit and Monsid did not have scientifically oriented questions in their lessons. Students conducted the investigations without knowing the purpose of the investigations. According to the NSES (National Research Council, 1996), hands-on activities do not guarantee inquiry. Students must have minds-on experiences. As the NSES (National Research Council, 1996: 20) explained, “Science teaching must involve students in inquiry-oriented investigations in which students interact with their teachers and peers. Students establish connections between their current knowledge of science and the scientific knowledge found in many sources; they apply science content to new questions; they engage in problem solving, planning, decision making, and group discussions; and they experience assessments that are consistent with an active approach to learning.”

With regard to the fact that the three teachers hold constructivist views of the teacher’s role and the student’s role in teaching science through IBI, this finding may stem from their familiarity with the NSCS (DCID, 2002) due to the fact that the Thai education has been reformed for almost 10 years (1999-2008). This assumption is consistent with the study of Sangpradit (2009) in which he reported all 37 science teachers (100%) who taught in schools participating in the EOLS Project answered that they taught science by following school curriculum that was based on the NSCS.

Instructional Objective

For instructional objectives, all three teachers understood that they should focus their lessons on scientific knowledge and science process skills. However, no one emphasized scientific attitudes as intended outcomes in their lessons. The teachers’ understandings of instructional objectives partially corresponded with the NSCS (DCID, 2002). According to the NSCS (DCID, 2002), science teaching and learning aimed to have students develop not only science content knowledge, but also science process skills and scientific attitudes. In the NSCS, learning activities in inquiry should develop learners in terms of logical thinking, designing and doing investigations, reviewing information from reliable resources, collecting and analyzing data, interacting with each other, formulating explanations based on evidence, answering problems or questions, and ultimately constructing knowledge.

The findings that the three teachers focused their IBI on scientific knowledge and science process skills may also stem from their familiarity with the NSCS as well as the teachers' constraint in trying to prepare students for the next level of education (secondary level). To be in a higher level of education, lower secondary level students were required to test the National Test [NT] and Ordinary National Educational Test [O-NET]. These tests place emphasis on scientific knowledge and science process skills. Thus this constraint may foster the teachers to focus their instructions on scientific knowledge and science process skills.

Instructional Process

With regard to classroom lesson introduction, the three teachers understood they should introduce an inquiry-based lesson by motivating students' interest. Their understandings aligned with the BSCS 5Es instructional model (Bybee *et al.*, 2006) and the 5Es inquiry process (DCID and IPST, 2002). Both of these science teaching models begins with an engagement phase. In this phase, the teachers motivated students' curiosity and tried to have students pose a question or be interested in a question provided by the teacher. However, the study found that only Suriya thought it was important to have scientifically oriented questions in his lessons. Suriya's understanding is consistent with the essential features of classroom inquiry defined by the National Research Council (2000). According to the National Research Council (2000), learners should be engaged in an inquiry-based classroom through a scientifically oriented question. However, the findings showed that all three teachers did not consider the significance of students' prior knowledge. None of them thought to elicit students' prior knowledge of the concepts. The teachers did not understand the role of prior knowledge in compliance with the constructivist perspective. These findings were partially consistent with the study of Soparat (2008). According Soparat (2008), the majority of 4^{th}-6^{th} grade teachers believed they introduced their science lessons by engaging students' interest or curiosity (48.4%, 46 teachers), considering students' prior knowledge (57.9%, 55 teachers), as well as telling students the objectives of the lessons (45.3%, 43 teachers).

In terms of investigation, all three teachers understood that students should conduct hands-on investigations and collect data. However, the teachers held different notions and implementation regarding scientific investigation. Phichit and Suriya believed students could use different types of scientific investigations to acquire knowledge; whereas Monsid viewed students should only use experiments to learn science. In this regard, Phichit's and Suriya's understandings were similar with the DCID and the IPST (2002). According to the DCID and the IPST (2002), scientific investigation was defined as methods for inquiring scientific knowledge. These methods required students to collect data, think logically, formulate hypothesis (or predictions), interpret data, and generate an explanation. The DCID and the IPST suggested that there were various methods of scientific investigations teachers could use for having students inquire about knowledge. These methods were, for example, observation, survey, experimentation, and review of information from learning resources. The understandings of Phichit and Suriya were consistent with the study of Ketsing and Roadrangka (2008) in that they found several science teachers (32.4%) in schools participating in the EOLS Project understood that IBI was a teaching method that allowed students to use various ways to acquire knowledge (e.g., experiment, discussion, and reading).

However, Phichit, Monsid and Suriya held different perspectives regarding the person who designed a scientific investigation. For Phichit, he thought the investigation could be developed by teacher, students, or both parties. Similar to Phichit, Monsid believed the teacher or students could be the one who designed the investigation. However, Suriya believed that students should be responsible for this duty. The findings revealed that Phichit's understanding complied with the National Research Council (2000). According to the National Research Council (2000), scientific investigation could be developed either by teacher, students, or both parties. It was dependent on the expected outcomes of the science teaching and learning.

With regards to the conclusion/explanation, Phichit, Monsid, and Suriya agreed that students should be responsible for analyzing data and formulating conclusions. Phichit and Monsid also knew that they should link the conclusions to a scientific concept in order to have students gain a deeper understanding of the concepts. The two teachers' understandings aligned with the BSCS 5Es instructional model (Bybee *et al.*, 2006) and the 5Es inquiry process (DCID and IPST, 2002). In the explanation phase of the two teaching models, learners formulated explanations based on data obtained from investigation. These models also stipulated that the teacher then introduces science concepts, process skills, or attitudes. The teacher's explanations aim to guide students toward a deeper understanding of the concepts.

However, the three teachers did not understand that they should connect the conclusions (new knowledge) with students' prior knowledge. Therefore, the teachers did not understand the role of prior knowledge in compliance with the constructivist's perspective. In a constructivist view, learning is the result of ongoing changes in an individual's mental framework as his/her attempt to make meaning of new experiences (Haury, 1993). An individual constructs meaning by assimilating or accommodating new experiences with his/her existing experience. Thus the teacher has to help students to connect their new experience or knowledge with their prior knowledge.

Furthermore, the findings indicated that all three teachers explained or had students learn the science concepts before doing investigations. The data reflected that the investigations were used for verifying the identified concepts. This notion was compatible with confirmation activities (Tafoya *et al.* 1980 cited in Bell, 2002). It was viewed as a teacher-directed type of inquiry within which the teacher provided questions, steps of procedure, and materials for learners. Learners conducted activities in an effort to rediscover identified phenomena (Tafoya *et al.*, 1980 cited in Bell, 2002). This type of inquiry was also similar with cookbook activities (National Research Council, 2000). In a cookbook activity, students learn science by following their teacher's lab directions. Students are informed what to observe, which data to collect, and how to analyze data (Colburn, 2000). In particular, teachers lecture or have students read about a concept or vocabulary before experiencing hands-on activities (National Research Council, 2000). Therefore, both confirmation activities and cookbook activities required students to conduct hands-on investigations in order to prove an identified concept or phenomena.

For communication, the three teachers understood that students should share their data and conclusions with others. Phichit believed communication was a way students learned from each other. The three teacher's understandings were consistent with the National Research Council (1996). According to the National Research Council (1996: 27), learners should communicate and justify their explanations with others. The National Research Council explained, "Sharing explanations provided others the opportunity to ask questions, examine evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations." This finding is also consistent with the study of Meinoratha (1997) and Bongkotphet (2009). According to Meinoratha, science teachers in schools participating in the EOLS Project typically motivated students to discuss data gathered from experiments. For Bongkotphet (2009), the case study teachers in her study understood that to teach astronomy through inquiry was to have students search for information, do reports, and then present their data with other students in the class.

With regard to group work, the three teachers held diverse notions regarding group work. Suriya understood students should learn science in groups. To learn in groups, he thought all the group's members should help each other to complete a task. Suriya also thought individual members should have specific roles and duties in groups. Consistent with Suriya, Phichit knew that students should learn science in groups and help each other to do a task. However, Phichit did not assign individual members roles and guidance. Phichit also had students learn in large groups. The two teachers' understandings aligned with the social constructivist perspective in that individuals constructed meaning of what they experienced through interactions with each other (e.g., teachers and peers) and with the environment they live in. Suriya's understanding also agreed with "positive interdependence" – one of five essential components of cooperative learning defined by Johnson and Johnson (1991). Johnson and Johnson explained "positive interdependence" existed when an individual group's members perceived they cannot succeed unless their group mates did. Individual members must coordinate their efforts to complete a task. To ensure positive interdependence, Johnson and Johnson suggested the teacher may assign individual students complementary roles. In the case of Monsid, he did not believe in group work. Monsid thought students should learn alone. For him, group work could not provide students comprehensive understanding.

In short, the findings regarding instructional process showed that the three teachers already conceived and practiced some key components of IBI. However, there were still a number of significant features that did not appear in their understandings and practices. These results may relate to the fact that the three teachers were familiar with the NSCS (DCID, 2002) and the Manual of Science Teaching and Learning (DCID and IPST, 2002). However, the teachers did not perceive an in-depth understanding regarding the constructivist theory that framed the science teaching and learning guidelines stipulated in the NSCS and the Manual of Science Teaching and Learning.

CHAPTER V

TEACHERS' UNDERSTANDINGS AND PRACTICES OF INQUIRY-BASED INSTRUCTION AFTER THE COLLABORATIVE ACTION RESEARCH PROGRAM

Introduction

This chapter presents the results of three case study teachers after they engaged in the Collaborative Action Research Program [CAR Program]. The chapter aims to address the research question: What is the Thai science teachers' understanding and practice of inquiry-based instruction after they engaged in the CAR Program. To answer the question, the data was gathered from multiple sources including individual interviews, teachers' inquiry-based lesson plans, classroom observations, teachers' written reflections, and central meetings. The data was initially examined through within-case analysis and then followed by cross-case analysis. The data was examined by considering the individual teachers' understanding and practice of IBI according to the four aspects of the essential features of IBI: role of the teacher, role of the student, instructional objective, and instructional process. The results are reported in individual cases. This is followed by common findings across the three cases. Lastly, a discussion of the results is provided. Pseudonyms used to represent the lower secondary teachers' names and the schools are the same ones used in previous chapters.

Teachers' Understandings and Practices of Inquiry-Based Instruction after the Collaborative Action Research Program

This section provides results from the three phases of collaborative action research with the teachers: CAR Cycle I, CAR Cycle II, and CAR Cycle III. These three phases covered the period of time the case study teachers participated in the CAR Program. To answer the research question, individual cases designed and implemented three inquiry-based lesson plans centered on their understanding of IBI. The teachers developed and taught one lesson per phase. For Phichit, he taught on the topic of chemical reactions between metal and acid in the CAR Cycle I; reflection of light in the CAR Cycle II; and refraction of light in the CAR Cycle III. Phichit implemented the lessons by following the 5Es inquiry process (DCID and IPST, 2002). This process is the one set out for teaching scientific inquiry in Thailand. The 5Es inquiry process involved five basic elements: engagement, exploration, explanation, elaboration, and evaluation. Monsid taught three lessons. These involved: a study of Mendel's work; the benefits and impacts of genetics; and living things in Thai Authid School's garden, respectively. Monsid implemented the lessons by following a numerical sequence in his lesson plans. Suriya's lessons dealth with: heredity, ecosystems, and environmental problems in the community. Suriya taught the lessons by following a three step process involving: introduction, instruction, and summary. After implementing each lesson, the teachers were interviewed individually regarding their understanding of IBI. The individual teachers then wrote a reflection on their instructional practice. At the end of each phase, the three teachers brought their lesson plan and teaching experience to share and discuss with the Collaborative Action Research Team [CAR Team] during central meetings. These meetings were video recorded.

Case I: Mr. Phichit

The Role of the Teacher: Teacher plays multiples roles.

Before attending the CAR Program, Phichit believed his roles in an inquiry-based classroom were those of a guide and a motivator. However, Phichit's understanding regarding the role of teacher was further developed after he attended the first central meeting with the CAR Team, designed his inquiry-based lesson plan on the topic of "Chemical Reaction between Metal and Acid", and implemented the lesson for 4 hours in his classroom. Phichit began to conceptualize that teachers assumed multiple roles in an inquiry-based classroom. This understanding became apparent in the first central meeting. As Phichit stated, "I think in inquiry teaching, my role is to guide and to tell students what the learning activity is and how to do it. There are many things that I as a teacher should do. But, most importantly I should encourage students to think logically, make conclusions, and share their ideas during discussion" (Activity I, central meeting #1: October, 2008). His response during the second interview reflected the same finding.

After Phichit attended the second and third meetings with the CAR Team, designed his inquiry-based lesson plans and taught the lessons in his classroom, his understanding regarding the multiplicity of teachers' roles was strengthened, as evidenced in interviews and lesson plans. During the third interview, Phichit indicated, "I took many roles in this lesson. I advised students how to conduct the experiment, prepared learning materials for them, and encouraged them to participate in experiment and discussion" (Phichit's interview #3: January, 2009). The lesson plan data reflected that Phichit also viewed himself as activity director in this lesson. As Phichit wrote, ". . . 1) Students are divided into 4 groups. Each group conducts the experiment on the topic of "Reflection of Light" on worksheet no.1 and worksheet no.2 and then answers questions on the worksheets" (Phichit's lesson plan #5: January, 2009). In the fourth interview, Phichit considered how he learned science with students through the learning activities. As he stated, "My role in this lesson was varied. I motivated students' interest. I advised and explained things students didn't understand. I also prepared learning materials for them. Most importantly, I think I learned the lesson with students through the learning activities" (Phichit's interview #4: February, 2009).

With regard to Phichit's practice before and after the professional development experience, the research findings revealed that his practice was considerably aligned with his understanding. Before Phichit attended the CAR Program, he taught his three inquiry-based lessons by taking the roles of guide, motivator, activity director, and lecturer. After engaging in the CAR Program, Phichit played the roles of guide, motivator, activity director and facilitator. However, he minimized his roles as activity director and lecturer. As Phichit stated,

> . . . After that, I asked students to share their ideas about how to examine the [chemical] reaction. Students shared many ideas. We then decided on steps that we planned to do the experiment. I then gave students a worksheet and told them that the worksheet was similar to our plan . . . At first, I didn't think about testing the pH of gas, but students said they wanted to. I then allowed them to study and revise the table . . . (Activity I, central meeting #2: December, 2009)

Phichit's inclusion of students' ideas into the design of the experiment is illustrated by the excerpt below.

Phichit:	We're going to design an experiment. How could we know whether acidic food and its container will have a reaction or not? Was the metal container corroded? Could you design an experiment to test this reaction?
Students:	Could we use meat?
Phichit:	What do we want to experiment? We want to experiment about how acidic food reacts with a metal container, right?
Students:	Yes.
Phichit:	So, we should use something that is a sample of a metal container.
Students:	Can we use a pot?
Phichit:	Yes, we can. But a pot is too big. We just want a piece of a pot. What is the material that pots are made of?
Students:	It's made from metal.
Phichit:	We should use something that is metal.
Students:	Can we use zinc? Can we use stainless steel?
Phichit:	(Phichit handles pieces of zinc and hides them behind his back.)
Students:	Can we use what you are holding?
Students:	Ice bucket?
Phichit:	Could you find me an ice bucket?
Students:	I can't find it now.

Phichit: Ok, I have already brought it. I cut an ice bucket into small pieces. (Phichit shows students pieces of zinc.) Could we use these?

Students: Yes!

(Phichit's classroom observation #4: November, 2008)

In his three lessons, Phichit did not present the scientific concepts before allowing students to conduct experiments. Rather he asked them to do the investigation and later learn the concepts.

Consistent with his understanding, Phichit's teaching practice in his second and third inquiry-based lessons highlighted the notion that the teacher role was multiple. As Phichit reflected:

> Things that I did in this lesson that helped students to learn were to motivate their curiosity on the topic being studied, to allow students to conduct hands-on activities, to encourage them to think critically of the activities they did, and to have students practice science process skills along with learning science concepts. (Phichit's reflection #5: January, 2009)

The Role of the Student: Student is active and minds-on investigator.

Before attending the professional development program, Phichit viewed the student role as active investigator. However, after he participated in the CAR Program, his notion regarding the student role was changed. Phichit conceptualized the role of the student as active and minds-on investigator[5]. He elaborated that students should participate in discussions, conduct hands-on activities, think critically and logically of

[5] The term "active investigator" refers to when students physically engage in the learning activity, without knowing the purpose or question that the activity intends to answer. Active and minds-on investigator refers to when students physically engage in the learning activity and also know purpose or question of the activity they engage in.

the activities, and significantly know problems or questions that the activities intended to address.

After Phichit attended the first meeting, designed an inquiry-based lesson plan, and taught the lesson, he began to view the role of students as active and minds-on investigators, as reflected in his responses during the second interview. Phichit stated, “In this lesson, the role of the students is that of participant in discussions. Students have to think of what they do and do it by themselves” (Phichit’s interview #2: November, 2008). This understanding also was reflected in the group discussion during the second meeting, as evidenced below.

Phichit: After that, I asked questions for motivating students’ interest. I tried to guide them to the objectives for doing the experiment, hypothesis and variables . . . Afterward, I provided them “questions before” and “questions after” the experiment. These questions aimed to guide students to the conclusion.

Educator: I think the results of the experiment should be in the middle between the “questions before” and the “questions after”.

Phichit: Do you mean put the “question before” before the experiment?

Educator: Yes, because the “questions before” aim to encourage “minds-on” participation. Minds-on refers to when students know the purpose of the activities they engage in. When students do experiments, we call this “hands-on”. But, students may not be minds-on during the experiment if they don’t know its purpose. So, we want students to understand what they do the activity for, what they should observe, and what evidence students should gain from the activity. Ultimately, this knowing will guide them to the conclusion. Thus inquiry requires both hands-on and minds-on.

(Central meeting #2: December 2008)

Phichit's response during the last interview also highlighted his notion of the student role as active and minds-on investigator. As Phichit considered, "Students are those who engage in hands-on activities. They know questions that the experiment intends to answer. They also present and discuss their data" (Phichit's interview #4: February, 2008).

With regard to Phichit's teaching practice both before and after the professional development program, the findings revealed that his practice was aligned with his understanding. In his lessons prior to the CAR Program, students played the role of active investigator. After Phichit engaged in the CAR Program, students in his lessons were both physically active and minds-on investigators consistent with his understanding.

In practice, Phichit encouraged students to participate in discussions, conduct hands-on activities, and think logically and critically of the activities they did, particularly in terms of problems or questions to investigate. In his three lessons during the three different phases, Phichit motivated students' interest and guided them to scientifically oriented questions. He also motivated students to think critically of the reasons behind their actions, as evidenced in an excerpt below.

Phichit: What are we going to do next?
Students: Put a piece of zinc into a test-tube (containing hydrochloric acid).
Phichit: Ok, put a piece of zinc into each test-tube. How do we put them in?
Students: We have to put them in at the same time.
Phichit: Why do we have to put them in at the same time?
Students: We want to control the experiment. So, they should be the same.

(Phichit's classroom observation #4: November, 2008)

The reflection data supported that the student role in Phichit's teaching practice was that of active and mind-on investigator. As Phichit wrote, "The student role is to design and conduct the experiment, analyze data, and make a conclusion. In order to make a conclusion, students must know the experimental question" (Phichit's reflection #4: November, 2008).

Instructional Objective: Teacher aims to develop students' scientific knowledge, science process skills and scientific attitudes.

Prior to the professional development experience, Phichit viewed the aims of teaching and learning science was to understand science concepts and to develop science process skills. However, after he experienced the CAR Program, Phichit's understanding was enriched. He began to accept that he should emphasize to students to not only learn science for scientific knowledge and science process skills but also scientific attitudes.

After Phichit attended the first central meeting, he began to conceptualize the goal of science teaching and learning, as evidenced in the discussion of the CAR Team during the first meeting below.

Phichit: For me, this paragraph [cut from the NSCS] tells me about the nature of science.

Researcher: Could you show me which part of the writing you think describes the nature of science?

Phichit: When it says, knowledge and the process for gathering the knowledge.

Researcher: Do you means science refers to both knowledge and process?

Phichit: Yes, it [science] includes both knowledge and process for getting the knowledge.

Researcher: What else do you see or understand from this paragraph?

Phichit: Students must present what they learn from inquiry.

Researcher: Yes, students must communicate their findings with each others.

Monsid: Yes, the paragraph tells me that we [teachers] should motivate students' interest. Students must learn how to collect data, analyze the data, ask a question, and answer the question. In brief, the Standards [NSCS] expect students to be able to think critically.

Suriya: Yes, it [NSCS] also expects students to be happy while they are learning science.

Researcher: Yes, it does. It's very important that students must enjoy learning science. Ok, what else do we learn from this paragraph?

Phichit: It must be in their habits. I mean science should be embedded in students' habits.

Researcher: What else?

Monsid: The Standards say "students should be provided". It doesn't state "students should do."

Researcher: Good point! The standards state about things in which students should be provided. If we look conversely as a science teacher, you may see the Standards imply what we should do or must do to help students learn science through inquiry.

Educator: Yes, the Standards want students to learn science through inquiry. But, children can't learn science through inquiry if teachers do not teach science through inquiry.

Researcher: Ok, now I think we should sum it up. Based on our discussion, I would conclude it into 5 items. First, science refers to not only content knowledge but also process skills and attitudes for inquiring the content knowledge. Thus, we as science teachers should teach science in all three aspects: scientific knowledge, science process skills and scientific attitudes. Second, the teacher should motivate students' curiosity about the topic being studied. Do not let students learn science without interest. Third, the teacher should encourage students to ask questions of natural phenomena. Fourth, the teacher should promote student happiness in learning science. Fifth, our teaching should provide students with opportunities to do investigation, collect data, analyze data, answer questions, and communicate their answers to others. Did I miss any points? Does anybody want to add or reject some of these conclusions?

CAR Team: No, we agree with these points.

(Activity I, central meeting #1: October, 2008)

The data from his lesson plans during the three different phases showed that Phichit wanted students to learn science by covering the three aspects. For scientific knowledge, he wanted students to understand chemical reactions between metal and acid, reflection of light, and refraction of light. In terms of science process skills, he expected students to do experiments, make experimental conclusions, and select methods suitable for presenting data. With regard to scientific attitudes, Phichit wanted students to be honest in recording data and work collaboratively with others in groups.

With regard to Phichit's teaching practice before and after he engaged in the professional development program, the findings showed that his practice was aligned with his understanding. For scientific knowledge, Phichit provided activities for students to learn chemical reactions between metal and acid, reflection of light, and refraction of light. For science process skills, Phichit gave the chance for students to pose experimental questions, do the experiments, and make experimental conclusions. However, in his lessons for the CAR Cycle II and the CAR Cycle III, Phichit did not ask students to select a method suitable for presenting their data. He assigned students to use a table on their worksheets. Phichit indicated during the interviews that he did not have time to cover this activity. In terms of promoting scientific attitudes, Phichit emphasized that students need to be honest in recording data. He also asked students to work collaboratively with others in a group. As Phichit wrote, "I encouraged students to be honest in recording data by telling them to record data according to what they saw as well as checking students' work while they were doing the experiment. I also told students to help each other to complete the experiment" (Phichit's reflection #4: November, 2008). However, in the lesson of the CAR Cycle II, students did not work collaboratively in groups because there were too many members in each group. Thus, some students did not participate in the group's work.

Phichit also reflected his concern of this issue in the group discussion during the third meeting, as provided below.

> At first, I wanted to divide students into 6 groups. But two sets of lab kits did not work. I then had to have 4 groups. However, when I set up four lab kits together, the electricity was not enough. So, only three sets were able to be used. Thus we finally had 3 groups. This was the problem. There were too many students in each group. Some students did the experiment while some just watched. I learned that having too many group members was not a good idea because I couldn't avoid the problem that many students were not on task. (Central meeting #3: January 2009)

Instructional Process

Classroom Lesson Introduction: Teacher begins the inquiry-based lesson by motivating students' curiosity, clarifying scientifically oriented questions, and eliciting students' prior knowledge.

Before attending the professional development program, Phichit believed he should introduce an inquiry-based lesson by motivating students' interest. However, after participating in the CAR Program, Phichit conceived that he should ask students' prior knowledge and also discuss with them about scientifically oriented questions.

After Phichit attended the first central meeting, designed an inquiry-based lesson plan, and implemented the lesson in his classroom, the data from interview and lesson plan showed that Phichit came to accept that, besides motivating students' curiosity, he should also elucidate the main question students are expected to answer, as well as uncover their prior knowledge. As Phichit stated, "I found out students' prior knowledge by asking them about acid, metal, and chemical reactions between acid and metal during discussion" (Phichit's interview #2: November, 2008). Phichit explained how he believed students were interested in the scientifically oriented question since the question was derived from their ideas, as shown in an excerpt below.

> Researcher: What is the main question that you want students to answer?
>
> Phichit: I want students to know the products of chemical reactions between metal and acid. So the question is, "What are the products of reactions between a metal container and an acidic food?"
>
> Researcher: Do you think students are interested in this question?
>
> Phichit: Yes I do because the question is from the students. I revise their questions. At first students ask me, "What's going on if we put a stainless steel spoon (metal) in orange curry (acidic food), what's the product of this reaction, and is it dangerous?" I then adjust their questions into, "What are the products of reactions between metal containers and acidic food?" However, in the experiment we use hydrochloric acid and zinc as samples of acidic food and a metal container. The question is then slightly changed into, "What are the products of reactions between zinc and hydrochloric acid?"
>
> (Phichit's interview #2: November, 2008)

In the lesson plan, Phichit raises an issue about current news to stimulate students' interest in the concept. He then discussed with students how this concept is and issue in their daily lives (e.g., acidic food and metal bowl). This understanding was also evidenced in the second meeting as illustrated below.

> In the engagement phase, I asked students about their prior knowledge which included chemical reactions, reactants, and products . . . students were able to answer the questions. They knew chemical reactions, reactants, and products. After that, I elicited students' knowledge about metal and nonmetal by showing many objects in the classroom and asking students to classify . . . I discussed with students about the chemical reaction between metal and acid found in our daily lives such as a stainless steel tea spoon in vinegar . . . after

that I asked students questions about how we could test the reaction. . . (Activity I, central meeting #2: December 2008)

After Phichit experienced the second and third cycles of collaborative action research, his understanding regarding the classroom lesson introduction was strengthened, as evidenced in the lesson plans, interviews, and central meetings. In his lesson plan of CAR Cycle II, Phichit planned to motivate students' interest in reflection of light, link the motivational activity to everyday experiences, and elicit students' prior knowledge by having students write their understanding on paper. Phichit narrated how he taught the lesson during the third meeting, as evidenced below.

Phichit: In the next step, I motivated students' interest. At my school, we had a science center room. I asked students to observe their images from three mirrors in that room and jot down what their images looked like. The room had plane, convex, and concave mirrors.

Monsid: You may have students draw pictures.

Suriya: I agree that seeing images from the mirrors could stimulate students' curiosity, but I am not sure about taking notes while they were observing . . .

Phichit: After students came to the class, I discussed with them about the images they saw. I then asked individual children to write their reason why the three mirrors had different images on Post-it notes and stuck them on the board.

Researcher: May I suggest something? I think observing their images was a good idea. But I want to add that you may have had students touch the mirrors because your purpose for this activity is to have students ask questions regarding the surfaces of the mirrors, right?

Phichit: Yes, I wanted students to ask why different kinds of mirrors produce different images. However, in practice, there were some students who reasoned it was because of the mirrors' surface. So, I could guide students to the experimental question . . .

(Central meeting #3: January 2009)

The data from his lesson of CAR Cycle III also showed that Phichit maintained his understanding regarding classroom lesson instruction. In his lesson, Phichit planned to promote students' curiosity by allowing them to observe a set of events related to the refraction of light. These were: 1) a letter viewed with the naked eye, 2) a letter behind a clear glass, 3) a letter behind a glass of water, 4) a chopstick in a clear glass, 5) a chopstick in a glass of water, 6) a coin in an empty cup, and 7) a coin in a cup of water. Like the lesson in CAR Cycle II, Phichit wanted students to write their current knowledge on paper. His response during the last interview showed that Phichit tried to have students pose questions to investigate, as illustrated below.

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

Phichit: The main question is, "How does light bend when it passes through different density mediums?"

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

Phichit: Yes, I do, because the question came from a student. Ploy, asked me, "Teacher, what is refraction?" I discussed her question with the whole class. We then agreed to investigate this question.

(Phichit's interview #4: February, 2009)

With regard to Phichit's teaching practice, the findings indicated that Phichit's practice before the CAR Program partially agreed with his understanding. In practice, besides motivating students' interest, Phichit also had students learn science concepts before doing investigation. However, his practice after the CAR Program was in agreement with his understanding. After the professional development experience, Phichit introduced his lessons of the three different phases by motivating students' interest, asking about students' prior knowledge, and guiding students to scientifically oriented questions. The excerpt below illustrated how students were motivated and led to the question.

Phichit:	Do you know the news about a woman who splashed acid onto another person?
Students:	Yes.
Phichit:	Could you tell me what's going on?
Students:	(Students narrate the news in detail.)
Phichit:	Do you know why acid is capable of damaging human-skin? Why doesn't that woman use water?
Students:	It can't damage our skin.
Phichit:	Anybody in this class know what acid is?
Students:	(Students raise their hands.)
Phichit:	How do you test an unknown liquid to see whether it is acid or not?
Students:	We may use litmus paper to test it. The paper will turn into a red color.
Phichit:	If you use blue litmus paper to test the unknown liquid, the paper will change from what color?
Students:	Blue to red.
Phichit:	Could we taste the unknown liquid?
Students:	We shouldn't taste it.
Students:	It's sour.
Phichit:	Yes it's sour. So, food that is sour should be what?
Students:	Acidic food.
Students:	Teacher, is it ok if we eat a lot of vinegar?
Phichit:	Is it acid?
Students:	It's acid because it's sour.
Students:	I think it's not good. It'll cause gastritis.
Phichit:	What will happen if we add organ curry (acidic food) in a zinc or a stainless steel bowl?
Students:	The bowl might be corroded.

Phichit: Where is the zinc after it is corroded?

Students: Dissolved in organ curry (acidic food).

Students: It might turn into gas.

Phichit: Is it healthy for eating?

Students: No, it's dangerous.

Students: Teacher, what's happened with the bowl? Is it dangerous?

Phichit: I don't know. That's why we conduct an experiment today. We're going to study the reaction between acidic food and a metal container. Thus, the experimental question is, "What are the products of a reaction between acidic food and a metal-made container?"

(Phichit's classroom observation #4: November, 2008)

In the lesson of the CAR Cycle II, after students observed their images from the three mirrors, they were asked to write answers for two questions: 1) What did the pictures they saw from the three mirrors look like and 2) What is the reason the three mirrors reflected dissimilar pictures. Phichit and students then discussed the activity. During the discussion, students asked, "Why do different types of mirrors reflect different images?" Phichit then linked the students' question to an experimental question which was, "How does light reflect when it shines on mirrors that have different surfaces?" Likewise, in the lesson of the CAR Cycle III, after students observed the set of events, they were asked to note the reasons that the seven events produced different images. Phichit then discussed the events with students. During the discussion, a student asked, "How does light bend when it passes through two different mediums?" Phichit then linked the question to an experimental question which was, "How does light bend when it passes through different density mediums?" Specifically, the question was, "How does light bend when it passes through air into a glass block, and when it passes from a glass block into the air?"

Investigation: Students learn science through hands-on investigation devised by teacher, students, or both parties. However, in practice the investigation is not designed by students.

Prior to the professional development experience, Phichit understood that students should acquire knowledge through hands-on investigations. Phichit believed students learned more when they physically engaged in natural phenomena. After Phichit participated in the CAR Program, he maintained his initial understanding that students should acquire knowledge by conducting hands-on activities.

After Phichit attended the three cycles of collaborative action research, the data from his lesson plans, interviews, and central meetings showed that Phichit maintained his initial understanding that in IBI students should learn science through hands-on investigation. In his lesson plans during the three different phases, Phichit wanted students to answer scientifically oriented questions by doing experiments. As Phichit wrote:

> . . . 1) Students work in groups of 6-7 members to conduct the experiment on the topic of chemical reaction between metal and acid. 2) Students discuss together about the purpose of the experiment, experimental procedure, and the answers of the questions before the experiment. (Phichit’s lesson plan #4: November, 2008)

After Phichit experienced the second cycle of the professional development program, he developed a technique for helping students to understand the investigation, as illustrated below.

Phichit: I drew pictures to help students track the steps of investigation. In the past, I only told them what to do and I had to tell them many times because students did not listen to me. Even though students read the experiment on a worksheet, they did not know what they were expected to do. When I used this technique, it helped me a lot.

Suriya: I think it is because they couldn't imagine.

Phichit: No, they couldn't imagine. It seems like they are able to understand pictures better than writing.

Monsid: I think if we ask them to do the things that are basic; we don't have to use pictures. I believe students could understand.

Phichit: Yes, the basic things such as lighting a candle or boiling water. For the lesson like mine, it is useful to draw pictures . . .

(Central meeting #3: January 2009)

With regard to Phichit's understanding of who should design investigations, Phichit initially believed that the investigation could be developed by the teacher, the student, or both parties. After he experienced the professional development program, Phichit still maintained his initial understanding. As Phichit responded:

Researcher: Who was the one to design the experiment?

Phichit: In this lesson (chemical reactions between metal and acid), I think students designed the experiment. I guided them to use zinc as a sample of a metal container and hydrochloric acid as a sample of acidic food. Students planned to put a piece of zinc into a test-tube of acid, and observe the reaction.

Researcher: Who was the person to design or make decisions about the data collection format used in the experiment?

Phichit: I assigned students to use a data table. But, students decided what they wanted to observe. They wanted to observe gas, color of the solution, dregs in the solution, corrosion of zinc, and test the pH of gas. I then allowed them to adjust the data table on the worksheet to fit the things they wanted to observe.

(Phichit's interview #2: November, 2008)

The data from his lesson plans of the CAR Cycle II and the CAR Cycle III supported Phichit's understanding in that the investigations could be developed by the teacher. In his lesson plans, Phichit wanted students to follow experimental procedures on worksheets. Phichit provided his reason for having students conduct the experiments on worksheet, as illustrated below.

Researcher: Why don't you provide students the opportunity to design this experiment?

Phichit: There are many reasons. First, I already have lab kits. Second, I want to save time. I think experiments on the lab kits are quite good. It provides clear light rays. It's easy to link the results to concepts.

Researcher: I wonder why some lessons you allow students to design the experiment while some you don't.

Phichit: What I mainly think about are time and materials. I also think about concepts. This concept isn't necessary for students to design their own experiment because the concept itself is clear. It's easy to link results to the concept . . . I use this experiment because I know it could help students clearly see light rays. I used to use candles and flashlights, but they couldn't produce clear enough light rays. So, students couldn't see the light rays' path.

(Phichit's interview #3: January, 2009)

With regard to Phichit's teaching practice before and after the professional development program, the findings revealed that his practice was somewhat compliant with his understanding. Before the CAR Program, Phichit provided opportunities for students to learn science through hands-on investigations. However, all the investigations were directed by the teacher. After the professional development experience, Phichit still provided the chance for students to do hands-on activities. However, he attempted to have more student involvement in the design of the experiments. In his three lessons during the three different phases, the experiments were developed by the teacher or both the teacher and students. In the lesson of the CAR Cycle I, Phichit provided the opportunity for students to design the experiment. In the CAR Cycle II and the CAR Cycle III, students conducted the experiments on worksheets. However, Phichit allowed students to select the degree of the angle of incidence they wanted to observe.

Conclusion/Explanation: Students are responsible for analyzing data and formulating conclusions.

Prior to the professional development program, Phichit already regarded that students should be the ones who analyze data and make conclusions. However, he accepted that it was difficult for students to do so. In addition, Phichit did not connect the conclusion (new understanding) with students' prior knowledge. After Phichit engaged in the CAR Program, he still maintained his initial understanding in that students were responsible for analyzing data and making conclusions. Both before and after the professional development experience, Phichit also wanted students to formulate conclusions based on evidence. However, he began to understand that he should link the new knowledge learned from investigation to students' prior knowledge. Phichit also learned to improve his strategy for helping students to generate their conclusions.

After experiencing the first cycle of collaborative action research, the data from lesson plan and interview showed that Phichit still believed that students were responsible for analyzing data and making conclusions. However, Phichit began to improve his strategy for helping students to formulate conclusions as illustrated in the interview below.

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

Phichit: I asked students to write their data on the board. I then gave them "questions after" the experiment and assigned students to answer the questions in their groups. After that, we discussed together in order to answer the questions. After the discussion, I

> gave students time for making a conclusion in their groups. I finally randomly selected some students in each group to tell his/her conclusion. During this period, I helped students to revise their conclusion until I felt they were able to make an appropriate conclusion.
>
> (Phichit's interview #2: November 2008)

In addition, Phichit came to conceptualize that he should link the conclusion to students' prior knowledge, as reflected in his question during the second central meeting. As Phichit stated, "I want to consult on how I can help students link their knowledge learned from an experiment to their prior knowledge because in the past students could not make the connection. When they finished the experiment, it also meant they finished the lesson." (Activity I, central meeting #2: December 2008)

After engaging in the second and third cycles of collaborative action research, the data from lesson plans, interviews, and meetings showed that Phichit maintained his understanding and strategy for helping students to analyze data and formulate conclusions. His understanding regarding the connection between new knowledge and prior knowledge was also strengthened, as shown in the third meeting below.

Phichit: After that I guide students to make a conclusion of the second activity. I began by reviewing the activity. I then asked students to draw light rays that were reflected from concave and convex mirror. After that I linked the results to the scientifically oriented question and pointed out students to compare the findings with their prior understanding that students wrote on Post-it notes.

Researcher: May I add? When Phichit discussed with students regarding the conclusion, he was so calm because at first many students did not see the relationship between angle of incidence and angle of reflection . . .

Phichit: I would say in the past I had never been so calm. If students couldn't answer my question, I suddenly told them the right answer. Now, I'm telling myself to wait for students to think and see the thing that I wanted them to understand.

(Central meeting #3: January 2009)

With regard to Phichit' teaching practice, the research findings revealed that Phichit's practice before the CAR Program was not in agreement with his understanding. Even though Phichit believed students should analyze data and formulate conclusions, in practice, he and students analyzed data together. Phichit then formulated conclusions for the students. However, while attending the professional development program, Phichit's teaching practice was considerably aligned with his understanding; expect the last lesson where Phichit did not connect the new knowledge with students' prior knowledge.

In his lessons of the three different phases, Phichit had students analyze data and make conclusions based on evidence gathered from the investigations. Phichit guided students to analyze data and make conclusions by following a similar strategy as described previously in his understanding. After reaching a conclusion for the lesson in the CAR Cycle I, Phichit did not connect the conclusion with students' prior knowledge even though he knew that he should. Phichit reasoned, "I did not link the conclusion to students' knowledge because I did not know how to do this. So, I only connected the conclusion with the concept" (Phichit's reflection #2: November 2008). In the lesson of the CAR Cycle II, Phichit linked the conclusion to both students' prior knowledge and to the related science concept. In the last lesson, Phichit did not link the conclusion with students' prior knowledge. Phichit responded during the interview that he forgot to link the conclusion to students' prior knowledge.

Communication: Students share their data and conclusions with others.

Initially, Phichit understood that students should share their data and conclusions with others. After participating in the CAR Program, Phichit still held the same notion regarding communication.

After experiencing the first and second cycles of collaborative action research, Phichit maintained his understanding in that students should share their data and conclusions with other students in the class. His lesson plans during the CAR Cycle I and the CAR Cycle II illustrated this. His response during the second interview also supported this finding, as evidenced below.

Researcher:	Did you allow students to share their data and conclusions with others?
Phichit:	If we're thinking as percent, it is only a few percent. Only two students communicated their findings. Actually, I want every group to present their data. However, I didn't have time. So, I had only two groups share.
Researcher:	What do you think communication is?
Phichit:	It is when we present the thing we understand to other people.
Researcher:	How could we communicate what we understand to others?
Phichit:	Talking, writing, Oh! I got it. Yesterday, I asked every group of students to write their data on the board.
Researcher:	Yes, you did. Students did share their data. So, writing data on the board is also a way to communicate.
Phichit:	At first, I thought communication was only talking.
Researcher:	Talking is a good way to communicate, but it is not the only way.

(Phichit's interview #2: November 2008)

Phichit's narration of his lesson during the third meeting provided further evidence that Phichit maintained his initial understanding, as illustrated below.

> In the third period (of the second lesson), I reviewed with students about what we did in the previous lessons. I drew pictures to remind them. After that, I asked each group of students to record their data on the board. We then discussed about the data. I tried to point out to students the relationship between the angle of incidence and the angle of reflection. So, students could see the conclusion. (Central meeting #3: January 2009)

After Phichit attended the last cycle of collaborative action research, he began to conceptualize that in addition to helping students learn to justify and evaluate their data and conclusions, communication was also a way for learning to listen to and respect alternative thoughts. As Phichit stated,

> Researcher: What do you see when students share their data with others?
>
> Phichit: They have more information. Some groups have missing data, so the others could help to fill in the gaps. Some groups do the experiment incorrectly. When they see data from other groups, it activates them to think about what went wrong. Communication helps students to have a more complete set of data. It also helps students to learn to listen to and accept other students' ideas.
>
> (Phichit's interview #4: February, 2009)

With regard to Phichit's teaching practice, the findings showed that before the professional development program, Phichit's practice partially agreed with his understanding. In practice, students communicated only their data. They did not share their conclusions. However, after the CAR Program, Phichit's teaching practice was compliant with his understanding. In his lessons from the three different phases, students had chances to share both data and conclusions with others, as illustrated in an excerpt below.

Phichit:	Now I want you to select a representative of your group. Then the representative will write data from the experiment on the blackboard, starting with group one.
Students:	(Students fill up the blackboard with their data.)
Phichit:	(Phichit writes four questions on another board.)
Phichit:	Students, look at the questions on the board. Students, work in groups to answer these questions. (Phichit reads the questions out loud.) Students, consult with your friends in the group. Talk with your friends and look at your data. Try to answer the questions. I'll ask each group to share the answers . . .
Phichit:	Ok, group one, when does the light reflect? Everybody listen when your friends are talking.
Students:	(Silent)
Phichit:	Yes, quiet and listen. So, when did the light reflect?
Student:	Light reflected when the medium was changed.
Phichit:	Did we change the medium?
Student:	I mean it reflected when it passed two different mediums. The light moved from medium one to medium two.

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

Group Work: Students learn science in groups.

Before attending the professional development program, Phichit already believed that students should learn science in groups. He knew that all group members should be involved in the work of the group. After participating in the professional development experience, Phichit maintained his initial understanding. Phichit's knowledge regarding students' learning through social interaction was also broadened.

After experiencing the first and second cycles of collaborative action research, Phichit began to understand the significance of students' learning through social interaction during group work, as evidenced in the discussion during the second meeting below.

Researcher: Do you know why Yupin [the teacher in the case story] assigned students to observe pillbugs as individuals and then had them talk in pairs?

Monsid: Because she wants students to cooperatively... something?

Phichit: Exchange ideas

Monsid: Yes, sharing information. I think individuals did not know much about the insect. So, Yupin may have individual students study information before asking them to observe.

Phichit: At this point, I think Yupin may want to broaden students' knowledge. When individual students observe pillbugs they may see something different from the others. So, when they work in groups, it helps them to know more.

(Activity II, central meeting #2: December 2008)

Phichit's conversation during the third meeting also showed that he recognized that students' interaction with the activity was decreased when there were too many students in a group. As Phichit stated:

> At first, I thought to divide students into 6 groups, but two sets of equipment were broken. So, I had to have 4 groups. However, when I connected the four sets with power, I found that there was not enough electricity for all. Only three sets of equipment were usable. So, now I had too many students in each group and a number of students did not engage in the activity. So, I learned that it is a bad idea to have too many students in one group. It certainly causes a problem. (Central meeting #3: January 2009)

After Phichit experienced the last cycle of collaborative action research, he learned how to address the problem of large groups. Instead of having two or three groups merge into one, Phichit had the groups share equipment. Phichit's response during the last interview showed that he still maintained his notion in that all group's member should be part of their group's work, as evidenced below.

Researcher: Could you tell me about the group work in this lesson? I notice it's different from the previous lesson.

Phichit: Yes, it is. In the last lesson, students didn't participate much in the experiment. It's because each group had too many students. But today, the groups were smaller. So, students could participate in the activity.

Researcher: What do you think?

Phichit: I think students were interested in the activity. It's hard to see someone who was off task. Everybody did the activity. All groups' members engaged in the activity.

(Phichit's interview #4: February, 2009)

With regard to Phichit's teaching practice, the findings revealed that before engaging in the CAR Program, his practice was not compliant with his understanding. In practice, even though students sat in groups, they learned as individuals. After Phichit attended the CAR Program, his practice was aligned with his understanding.

In his lessons during the three different phases, Phichit assigned students to learn in groups. Each group still contained students of mixed-gender and ability. Phichit did not assign roles and duties for individual students. However, he encouraged students to participate in the learning activities. As Phichit reflected, "I tell students to help each other to conduct the experiment and record data. I also check their work progress when they do the experiment" (Phichit's reflection #6: February, 2009). According to classroom observations, it was found that in the lessons of the CAR Cycle I and the CAR Cycle III, almost all of the students participated in the activities. But, a number of students did not engage in the learning activities in the lesson of the CAR Cycle II. As Phichit indicated previously, there were too many students in each group. A group had around 13-14 members.

Case II: Mr. Monsid

The Role of the Teacher: Teacher plays multiple roles.

Initially, Monsid conceived that the teacher had multiple roles in an inquiry-based classroom. These roles were comprised of guide, facilitator, motivator, activity director and lecturer. Throughout his participation in the CAR Program, Monsid maintained the notion regarding the multiple roles of the teacher, with the exception being that he did not view himself as a lecturer. Monsid also broadened his understanding in terms of the degree of guidance a teacher should provide in inquiry-based lessons.

After Monsid attended the first central meeting, developed an inquiry-based lesson plan on the topic of “A Study of Mendel’s Work”, and taught the lesson for 3 hours, he was interviewed regarding his understanding of IBI. Monsid’s response during the interview showed that he retained his view that the teacher had multiple roles. However, his understanding was broadened in that he viewed that the teacher should assume roles that promote students’ interest and willingness to do inquiry. As Monsid stated, “I think the role of teacher is whatever. Teachers may be activity director, assistant, motivator, or facilitator. The important thing is to encourage students to be interested in topics being studied and to have them do inquiry with enthusiasm . . .” (Monsid’s interview #2: November, 2008). The data reflected that Monsid shifted his focus regarding the role of the teacher from himself to students. He began to think of what students gained and then considered what he should do to assist them. Thus, it appeared that Monsid’s understanding shifted to a more learner-centered approach.

After attending the second meeting, designing a new inquiry-based lesson plan on the topic of “The Benefits and Impacts of Genetics”, and implementing the lesson for 3 hours in his classroom, Monsid’s understanding of the role of the teacher was enriched, particularly in terms of the degree of the teacher’s guidance and direction of the learning activity. Monsid indicated his guidance could be varied, depending on each concept of study. As he explained:

> If I teach a concept that is difficult to understand, I should control the learning activities. I think students couldn't achieve the expected learning outcomes if I let them control the lesson. On the other hand, if I teach a concept that doesn't require students to think a lot, I may allow them to control the lesson. For example, ecosystems, I may ask students to design a learning activity or develop an experiment. However, I still have to provide them a framework. (Monsid's interview #3: January, 2009)

After implementing his last inquiry-based lesson on the topic of "Living Things in Thai Authid School's Garden" for 4 hours, Monsid was interviewed regarding his understanding of IBI. His answers verified that Monsid maintained his view of the multiple roles of the teacher. As Monsid explained:

> I took many roles in this lesson. I designed the learning activities and guided students how to do the activities. I discussed the data and conclusion with students. I advised them where to get information. I also answered their questions. However, I didn't tell them the conclusion . . . (Monsid's interview #4: February, 2009)

With regard to Monsid's teaching practice before and after the professional development experience, the research findings revealed that his practice agreed with his understanding. Prior to his participation in the CAR Program, Monsid performed multiple roles in his inquiry-based classrooms. These were motivator, activity director, guide, and facilitator. However, contrast to what he said; Monsid was not a lecturer in his classroom. He did not provide scientific knowledge before asking students to do the investigation.

After attending each central meeting and designing an inquiry-based lesson plan, Monsid's teaching practice showed that he assumed multiple roles in his three lessons during the three different phases. His roles were motivator, activity director, guide, and facilitator. In practice, Monsid motivated students' interest, provided questions to investigate, gave students investigational procedures, guided them how to do the investigations, and assisted students in how to analyze data as well as to formulate conclusions. He also prepared learning materials for them. As Monsid reflected,

> I posed the main questions and motivated students to be interested in the questions . . . I planned the investigation and provided the chance for students to analyze data gathered from textbooks and worksheets. Students answered my questions by using their prior knowledge combined with information from the learning resources. I wrote what they found [from textbook and worksheets] on the board and guided them in how to answer the questions appropriately. (Monsid's reflection #5: January, 2009)

Monsid's roles as motivator, activity director, and facilitator were reflected in an excerpt below.

Monsid:	Yesterday, I taught this lesson for students in another class. We surveyed organisms in the garden and found many animals . . . What do you think are requisites living organisms need for their lives. What do we need for survival?
Students:	Food, air, water, medicine, money
Monsid:	Yes, living things need food, air, and medicine. Many animals know how to use medicine such as a cat and dog, or even a pig . . .
Monsid:	What else do animals need for their lives?
Students:	(Silent)
Monsid:	Do they need nests? Their habitats?
Students:	Yes.
Monsid:	. . .
Students:	. . .

Monsid: Let’s talk about our school’s garden. What do you think? What kinds of animals live in the garden? What are the animals that have their homes in our garden?

Students: Mosquitoes, toads, lizards, bees, butterflies, ants (Monsid writes the answers on the blackboard.)

Monsid: But, are you sure? How do we know your prediction is right?

Students: Go to the garden and see.

Monsid: Yes, today we’re going to explore the garden and observe the living things there. When going to the garden, I want you to observe the animals and their habitat . . . Everybody draw 1-2 pictures of animals you find . . . Students, please also write the animal’s name and where you find it on the pictures. You will have 20 minutes to complete the survey. Come back to this room when you’re done. Now, come to get equipment, and then wait for me outside the room.

(Monsid’s classroom observation #6: February, 2009)

The Role of the Student: Students are active and minds-on investigators.

Like Phichit, after Monsid received the professional development experience, he understood that the role of the student was active and minds-on investigator. Initially, Monsid believed the role of student was that of an active investigator.

After Monsid attended the first cycle of the professional development program [CAR Cycle I], he maintained his initial understanding regarding the role of the student as active investigator. Monsid viewed students were those who completed learning activities by following their teacher’s direction. As Monsid stated, “Students were the ones who followed my activities. Actually, students did not know that they followed my direction . . .” (Monsid’ interview #2: November 2008).

However, Monsid’s response during the interview showed that his pedagogical content knowledge was broadened. Monsid considered his amount of direction for students was dependent on the concept of study. He was aware that for some scientific concepts and contents he needed to use specific levels of support for his students. As Monsid explained:

Monsid: The role of the students is decided by the concept being focused on. Some concepts, such as population, I may allow students to design an investigation or even control the lesson. However, the concepts that have a lot of details [difficult concept] such as cells and plants, I think I should direct them . . .

Researcher: Could you tell me more about the concepts that you don't allow students to direct the lesson?

Monsid: The concepts that have many scientific terms [difficult concepts]. I think teachers shouldn't allow students to design learning activities. If the concepts have less scientific jargon [easy concept] such as ecosystems, climate, and matters in daily lives, teachers may have students develop activities. But, if I teach about atoms, I couldn't have students plan the learning activity.

Researcher: Why atoms?

Monsid: Atoms are easy to misunderstand. The concept is also a basis for many other concepts. If students don't understand this concept, they couldn't understand many concepts relating to atoms.

(Monsid's interview #2: November, 2008)

After Monsid experienced the second cycle of collaborative action research [CAR Cycle II], he began to conceptualize that the student role was active and minds-on investigator, as evidenced in his answers during the third interview. Monsid stated, "In this lesson, I told students questions to investigate. I then assigned them to answer the questions by reviewing information from textbooks. After that, we discussed about what students found together . . ." (Monsid's interview #3: January, 2009). In the last interview, this notion was also highlighted. For Monsid, active and minds-on investigator referred to those who did investigations, knew which questions to investigate, participated in discussions, and formulated conclusions.

With regard to Monsid's teaching practice, the findings revealed that his teaching was compliant with his understanding. In Monsid's teachings during the three phases, students were asked to share ideas in discussions, conduct investigations, present their findings, analyze data, and formulate conclusions. Students were given questions to investigate. However, they did not have a chance to pose their own questions and develop their method of investigation. Students followed Monsid's steps of investigation and answered his questions, as shown in an excerpt below.

Monsid: Students look at the picture. Do you think these children are normal?

Students: No, they aren't. Their stomachs are swollen. Their legs also bend.

Monsid: Do you know what disease they have?

Students: Don't know/Thalassemia.

Monsid: Oh! Someone already knew the Thalassemia disease. Do you know how it is transmitted to others?

Students: Not sure/don't know.

Monsid: Ok. Many of you don't know. So, we're going study the Thalassemia disease. I have four questions for you. (Monsid writes the questions on the board and reads out loud.) The questions include: 1) What is the cause of Thalassemia? 2) How does the disease get transmitted to others? 3) What could you do to control the disease? and 4) What are the benefits and impacts of genetic knowledge in this case? Students work in groups to answer these questions. Look at information in textbooks and worksheets. (Monsid distributes worksheets for students.) After that, I'll have you share your answers.

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

Instructional Objective: Teacher aims to develop students' scientific knowledge, science process skills, and scientific attitudes.

Similar with Phichit, prior to the CAR Program, Monsid focused his teaching only on scientific knowledge and science process skills. After he participated in the professional development experience, Monsid broadened his understanding regarding the aim of teaching and learning science. He focused his teaching to include scientific knowledge, science process skills, and scientific attitudes consistent with the NSCS.

Like Phichit, Monsid began to reconceptualize the goal of science teaching after he attended the first central meeting, as evidenced in the discussion with the CAR Team during the first meeting above. The data from his lesson plans for the three different phases revealed that Monsid focused his lessons on the three aspects. For scientific knowledge, Monsid wanted students to explain dominant and recessive characteristics, to give reasons for using a pea plant in Mendel's experiment, to explain cause of the Thalassemia disease, to suggest a method for controlling the disease, to understand the benefits and impacts of genetic knowledge, and to explain a predation relationship among organisms. In terms of science process skills, Monsid expected students to review information regarding Mendel's experiment, make a pedigree of pea plant inheritance, search for information regarding the Thalassemia disease, survey and classify living organisms in the school's garden, and draw a food chain. With regard to scientific attitudes, he wanted students to share ideas in discussions and work collaboratively with others in groups.

With regard to Monsid's teaching practice, the findings showed that Monsid's practice was consistent with his understanding both before and after the professional development program. As Monsid indicated:

> If I look at the Standards, I know that the Standards want students to develop not only scientific knowledge but also skills and attitudes. In the past, when I taught science I focused mainly on knowledge. I did not concern myself much

about skills and attitudes. Now, I'm trying to incorporate more skills and attitudes in my teaching. (Monsid's reflection #4: November, 2008)

In terms of scientific knowledge, Monsid provided activities for students to learn about dominant and recessive characteristics, reasons for using a pea plant in Mendel's experiments, causes of the Thalassemia disease, methods for controlling the disease, benefits and impacts of genetic knowledge, and a predation relationship of organisms. For science process skills, he gave the chance for students to review information of Mendel's experiment and Thalassemia disease from reliable resources (textbooks and worksheets). He assigned students the task of producing a pedigree of a pea plant's characteristics, to survey organisms in the school's garden and classify them, and to draw a predation relationship of the animals. With respect to scientific attitudes, Monsid asked students to work in small groups (4-5 students) and discussed their findings with them.

Instructional Process

Classroom Lesson Introduction: Teacher begins the inquiry-based lesson by motivating students' curiosity, clarifying scientifically oriented questions, and eliciting students' prior knowledge.

Similar with Phichit, before Monsid engaged in the CAR Program, he believed that he should introduce his inquiry-based lesson by motivating students' interest. Monsid normally stimulated students' curiosity through discussion and narration of a story about scientists. After Monsid attended the CAR Program, his understanding regarding classroom lesson introduction was broadened. Monsid realized that, besides stimulating students' curiosity, he should clarify the main question that students are expected to answer and assess students' prior knowledge of the concept being focused on.

After experiencing the first cycle of the CAR Program, the data from interviews and lesson plans showed that Monsid began to perceive that, besides motivating students' curiosity, he should also inform them of the main question that students are expected to answer, as well as find out their prior knowledge. In his lesson of the CAR Cycle I, Monsid planned to motivate students' interest by asking them to compare and contrast their inherited characteristics (e.g., ear lobes, tongue, and thumb) with parents, relatives, and classmates. After that, he wanted to access students' prior knowledge of Mendel and his work by showing them Mendel's portrait and then asking questions such as who is in this picture what did he do in the field of biological science. Monsid then planned to give students a pedigree of pea plants' flowers based on Mendel's experiment and ask them to answer, "What is the factor that causes the 1st generation pea plant to have only purple flowers and the 2nd generation to have both purple and white flowers?"

After participating in the second and third cycles of collaborative action research, the findings indicated that Monsid maintained his understanding regarding the classroom lesson introduction. In the lesson for the CAR Cycle II, Monsid planned to motivate students' interest by showing pictures of Thalassemia patients and then asking about their existing knowledge of the disease. As Monsid stated:

> I introduced this lesson by showing pictures of Thalassemia patients because I wanted students to feel the disease was close to their lives. When they saw the pictures, students began to think. Some students thought the patients looked like them. Students were interested in the lesson. By doing so, I also recognized how many students knew about the disease. (Monsid's interview #3: January, 2009)

In this lesson, Monsid wanted students to answer four questions including: 1) the cause of the Thalassemia disease; 2) the way the disease contracts to others; 3) the way to control the disease; and 4) the benefits of genetic knowledge in relation to the disease. In his last inquiry-based lesson, Monsid planned to stimulate students' curiosity by discussing factors that living organisms need for survival. Monsid wanted students to survey the school's garden in order to answer, "What kinds of living things live in the school's garden?" Before doing the survey, Monsid wanted students to predict the types of living things they would see in the garden.

With regard to Monsid's teaching practice before and after the professional development experience, the results indicated that, for most part, Monsid implemented his lessons by following his beliefs. In his lessons during the three different phases, Monsid began by motivating students' interest. After that, he asked students' prior knowledge and provided them scientifically oriented questions. In his classroom of the CAR Cycle I. Monsid motivated students' interest by discussion about students' inherited characteristics. He asked students' prior knowledge about Mendel and his study. However, none of the students knew Mendel and his work. Monsid then narrated a story of Mendel, provided students a pedigree of a pea plant's flower and then questions to investigate.

In the inquiry-based classroom of the CAR Cycle II, after Monsid motivated students' interest, he asked questions, for example, "Do you think the children are normal; have you ever seen people look like those in the pictures; what is the disease they have; what is the cause of the disease; and how does it contract to others?" Some students recognized the disease. But, none of them knew the cause of the disease and how to control the disease. Monsid then assigned students to answer the four main questions by reviewing information from the textbook and worksheets. In his classroom of the CAR Cycle III, after Monsid discussed with students regarding factors living things need for life, he told students the main question they were expected to answer through survey. The question was, "What kinds of animals live in the school's garden?" He then asked students to predict which types of living things were in the garden.

Investigation: Students should learn science through hands-on investigation devised by the teacher, students, or both parties. However, in practice the investigation is designed only by the teacher.

Before engaging in the CAR Program, Monsid believed experimenting was the only appropriate method for students to learn science. He thought searching information from learning resources was not a method for studying science in IBI. However, after he experienced the professional development program, his understanding shifted. Monsid accepted that there were various methods of inquiry students could employ for addressing scientifically oriented questions. This understanding was reflected in his lesson plans and interviews in which Monsid designed to have students answer scientifically oriented questions by reviewing information from reliable sources and doing a survey.

After Monsid attended the first cycle of the CAR Program, the findings indicated that Monsid began to accept that reviewing information from reliable sources was a method of scientific investigation. In his lesson plan for the CAR Cycle I, Monsid intended to have students address scientific questions by reviewing information from reliable resources. Monsid's new understanding may be the outcome of his participation in the group discussion between Phichit and the science educator, as illustrated below.

Phichit: I would like to consult with the CAR Team about when I ask students to search or review information from textbooks or the Web. Is this inquiry?

CAR Team: (Silent.)

Educator: I would say it can be inquiry. However, we must ask students to synthesize the data they get from, for example, the internet. Inquiry doesn't mean only copying what it says on the internet and then sending a whole bunch of information to teachers. But, we need to have students synthesize the information. We may use questions to guide them. The questions must help students to think critically.

Phichit: Think critically about the information they have, right?

Educator: Yes, for example, when we assign students to gather information regarding GMOs, we should assist them to answer what GMOs are and why scientists classify GMOs as a biotechnology. We [science teachers] must create questions that help students analyze the information, think critically . . .

(Activity I, central meeting #1: October, 2008)

The data from his lesson plan of the CAR Cycle II also supported the idea that Monsid accepted that reviewing information from reliable sources was another method for doing inquiry. In his plan, students were expected to answer the questions by gathering information from textbooks and worksheets and then discuss the information with the whole class. The lesson plan of the CAR Cycle III showed that Monsid conceived doing a survey as another method of investigation in inquiry. In his lesson, students were assigned to explore living things in their school's garden.

With regard to Monsid's understanding of the one who should develop the investigation, Monsid initially believed that the experiment could be devised by the teacher or students. After he participated in the CAR Program, his understanding was a bit broadened. Monsid considered that the investigation could be developed by the teacher, student, or both parties. After Monsid experienced the first cycle of collaborative action research, he accepted that the investigation could be developed by the teacher, student, or both. As Monsid stated, ". . . I think learning activities could be developed by the teacher, students, or both of us. However, I couldn't let students design the activities in the lessons where I don't have a deep content knowledge" (Monsid's interview #2: November, 2008).

With respect to Monsid's teaching practice before and after the CAR Program, the findings showed that his practice was somewhat aligned with his understanding. Prior to the professional development experience, Monsid had students do experiments and observe demonstrations designed by the teacher. After the CAR Program, students learned science through reviewing information from reliable resources and doing a survey. However, the investigations were designed only by the teacher. The excerpt below illustrates how Monsid would direct students during investigations.

> Today we're going to explore the garden and observe the living things that live there. When going to the garden, I want you to observe the animals and their habitat . . . Everybody draw 1-2 pictures of the animals you find. Do not draw pictures of the same animals if you are in the same group. Students, please also write the animal's name and where you find it on the pictures. You will have 20 minutes to complete the survey. Come back to this room when you're done . . . (Monsid's classroom observation #6: February, 2009)

Conclusion/Explanation: Students should be responsible for analyzing data and formulating conclusions.

Before engaging in the CAR Program, Monsid already knew that students should be responsible for analyzing data and formulating conclusions. However, he did not know that he should link the conclusions with students' prior knowledge. After participating in the CAR Program, Monsid began to conceptualize the notion of linking the conclusions with students' prior knowledge in the last phase.

Although there were a number of conversations regarding the connection between new knowledge and prior knowledge that occurred during the first and second meeting, Monsid did not understand this idea, as evidenced in his lesson plan and interview. In his lesson plans of the CAR Cycle I and the CAR Cycle II, Monsid planned to have students share the information gathered from textbooks or worksheets. He planned to discuss this information with students in order to help them analyze data and formulate appropriate answers. After that, Monsid intended to connect the answers to related science concepts. However, he did not plan to link the conclusions with students' prior knowledge. Monsid's response during the second interview also reflected that he did not have a clear understanding regarding the notion of linking new knowledge with prior knowledge.

Researcher: How do you connect the knowledge students learned from the activity to their prior knowledge?

Monsid: I found that students had prior knowledge regarding genes and chromosomes. However, I couldn't connect the knowledge in this lesson because students have not learned the scientific terms.

Researcher: I mean the students' prior knowledge about Mendel and his work. At the beginning of the lesson, I recognized that you asked students' prior knowledge regarding Mendel and his experiment.

Monsid: Yes. But, I think in this lesson I was talking only about Mendel and his work. The concepts were already related with each other.

Researcher: So, you believed you already connected the new knowledge with students' prior knowledge?

Monsid: I think whatever I did in this lesson was linked with Mendel and his work.

(Monsid's interview #2: December 2008)

After participating in the last cycle of collaborative action research, Monsid began to conceive that he should link the new knowledge with students' prior knowledge. In his lesson plan, Monsid planned to connect the conclusion with students' prior knowledge.

The findings revealed that Monsid's practice after the CAR Program was compliant with his understanding. Monsid maintained his understanding that students should analyze data and make conclusions. As Monsid wrote, "At first, I had students share their information from textbooks and worksheets. I wrote their information on the board. We then discussed the information and generated appropriate answers together" (Monsid's reflection #5: January 2009). In the last reflection, Monsid wrote, "To answer the question, students presented their data. I wrote the data on the board and asked them to classify the animals using their criteria. I then assisted students to answer the question" (Monsid's reflection #6: February 2009). After having conclusions of each lesson, Monsid connected the conclusions with related science concepts. However, he linked the conclusions with students' prior knowledge only in his last lesson.

Communication: Students share their data and conclusions with others.

Prior to the CAR Program, Monsid understood that students should share both data and conclusions with other students in his class. After attending the professional development program, Monsid maintained the same understanding.

Monsid's response during the second interview illustrated that he believed students should communicate their data and conclusions to others. As Monsid stated, "In this lesson, students had chances to talk with each other in two levels. First, students talked to their peers in the group. Second, they presented their findings to other groups . . ." (Monsid's interview #2: November, 2008). In the lesson plans, Monsid wanted students to communicate via whole class discussions and written presentations. This was evident in Monsid's lesson plan where he wrote,

1) Each group of students presents their data of living things (by sticking pictures on the board).
2) Students work in groups to classify the living things based on their criteria.
3) Students present their classifications (by sticking classification diagrams on the board).
4) Students and the teacher discuss about the data and classification.
5) Students compare the findings with their prediction.
6) Students work in groups to write the relationships (predator-prey) among the organisms in the garden.
7) Students present their work in front of the class.

8) Students and the teacher discuss about the predation relationship and the food chain.

(Monsid's lesson plan #6: February, 2009)

With regard to Monsid's teaching practice, the findings indicated that before the CAR Program Monsid's practice partially coincided with his understanding. In practice, students had chances to share their data with other students. However, they did not share their conclusions in some lessons. After the CAR Program, Monsid's practice was in agreement with his understanding. Monsid had students share both data and conclusions with others in his three lessons.

Group Work: Students learn science in groups.

Prior to the CAR Program, Monsid believed students should learn science as individuals. After engaging in the professional development program, his understanding shifted. Monsid conceptualized that students should learn science in groups.

After experiencing the first cycle of collaborative action research, Monsid recognized the importance of students' learning by interacting with each other in groups, as evidenced in his response during the second interview.

Researcher: What kind of work requires many students?

Monsid: The work that has details, for instance, the work where students have to do an experiment. This kind of work requires the one who does the work, the one who cleans the equipment, and the one who returns them. On the other hands, the work that requires students to share only their thoughts, it doesn't need many students. In fact, only one could do. But, the one couldn't gain comprehensive understanding. For example, if I ask a student to look at the data of a pea plant's flowers, he/she may see only color. A student may not think about dominant and recessive characteristics because there is no one to talk to.

Researcher: So, you think if you have more than one student, their ideas are broadened, correct?

Monsid: Yes, it is.

(Monsid' interview #2: November, 2008)

After engaging in the second cycle of collaborative action research, Monsid's understanding regarding students' learning through interacting with each other in groups was strengthened, as illustrated in his response during the third interview.

Researcher: What is your reason for providing students freedom to select their group's members?

Monsid: I want to build an informal atmosphere. I think students learn better when they work with others they are familiar with or the ones they like. It is easy for them to talk and share their thoughts. Students feel free to work together. They could also finish the work quickly. . .

(Monsid's interview #3: January, 2009)

Monsid's response during the third interview also reflected his dramatic change in understanding of group work. For Monsid, group work referred to a group where all the group's members are involved in the work of group. As Monsid indicated:

Researcher: What do you think about group work? What should students do to build up cooperative group work?

Monsid: I think it's like when we work in groups, we have to help each other to think, plan, and act. This is group work. Students could be at any step of these three. The point is they have to be part of their group's success. A student might think. Some of them might think and do. Some might think, plan, and act. For me, this is group work.

(Monsid' interview #3: January, 2009)

The research findings revealed that, before the CAR Program, Monsid's teaching practice partially agreed with his understanding about group work. Monsid believed students should learn as individuals. In practice, he had students learn individually and in large groups. After the CAR Program, the teacher's practice was compliant with his understanding. Monsid had students learn in small groups. As Monsid reflected, "Students worked in groups throughout the learning activities. They chose their members. However, I limited each group to have around 4-5 students" (Monsid's reflection #6: February, 2009). However, Monsid did not assign roles or duties for individual students when they worked in groups. By providing specific role and duty, a teacher helps students to avoid redundant efforts for doing the task. It also promotes students' coordination in group work (Johnson and Johnson, 1991).

Case III: Mr. Suriya

The Role of the Teacher: Teacher should be guide, facilitator, and motivator; however in practice teacher plays multiple roles.

Prior to his participation in the professional development program, Suriya viewed the teacher role as guide and facilitator. As the teacher professional development experience progressed, Suriya's conception of the teacher role was broadened. He accepted that the role of the teacher was guide, facilitator, and motivator.

After Suriya attended the first central meeting, developed an inquiry-based lesson plan on the topic of "Heredity", and taught the lesson for 3 hours, the teacher was interviewed regarding his understanding of IBI. Suriya's response from the interview showed that he his view that the role of the teacher was guide and facilitator had not changed. Suriya did not view the teacher as an activity director. As he stated:

> In this lesson, my role was a director because students didn't play their role. So, I had to tell them what they should do. In fact, I think students should be the leaders [of the learning activity] and I should be only an assistant. Students should think and take action on the learning activities. Students should be able to complete the activities by themselves. I wish students could do this, but practically they couldn't. (Suriya's interview #2: November, 2008)

The data from group discussion also reflected that Suriya believed the teacher should not be an activity director and that students should assume this role.

> Suriya: When I teach students, I try not to tell them anything because we already made an agreement in that students must prepare themselves before the class.
>
> Educator: Could you explain more?
>
> Suriya: We already set up the topics we are going to study throughout the whole semester. So, students know the topic or experiment they are going to study in every lesson. Students must read the textbook or worksheet [regarding concepts being studied] before attending the lesson . . . So, when we are in the classroom, I think they should know what they should do. I don't have to tell them. Students could be able to do the experiment. But, practically, students never prepared. They just waited for me to tell them what they should do.
>
> (Activity I, central meeting #1: October, 2008)

After Suriya engaged in the second meeting, developed his new inquiry-based lesson plan on the topic of "Ecosystems" and implemented the lesson for 5 hours, he began to conceptualize a new role of the science teacher as motivator, as shown in his answers of the third interview.

> Researcher: What do you view as your role in this lesson?
>
> Suriya: I think my role was as an assistant.

Researcher: Could you explain what the assistant should do?

Suriya: He should assist students in everything they need such as motivating their interest, guiding them how to design the survey, doing the activity, and preparing learning materials for them.

(Suriya's interview #3: January, 2009)

Suriya's understanding of the teacher role as motivator was also shown in the group discussion of the third central meeting, as illustrated below.

> For the teaching and learning process, I began by motivating students' curiosity. I divided students into groups. Each group had 3-4 students . . . I raised issues for discussion. However, I found it was difficult to ask questions because normally I did not ask questions. I typically assigned them to design the activity. But, when I used this approach I felt students had more interest on the learning activity even though some students did not answer the questions. It was probably because my questions were not clear . . . (Central meeting #3: January, 2009)

After implementing the last lesson on the topic of "Environmental Problems in the Community" for 2 hours, Suriya was interviewed regarding his understanding of IBI. His response revealed that he viewed the teacher role as guide, facilitator, and motivator, but not the director of student activities. In the fourth meeting, Suriya revealed the same ideas. He stated, "I think my role is to assist and support students in the learning activity. For example, I gave them equipment and material for the experiment. Students thought by themselves of what they should do. I believe students should be able to do the activity on their own" (Central meeting #4: February 2009).

The findings of Suriya's teaching practice before and after the professional development program showed that there was an inconsistency between his understanding and practice. Before the CAR Program, Suriya assumed multiple roles in his lessons (activity director, motivator, guide, facilitator, and lecturer) even though he viewed himself only playing the role of guide and facilitator.

After Suriya attended the central meetings, implemented inquiry-based lessons, and wrote reflections of his practices, the data showed that Suriya played many roles in his lessons during the three different phases. These included activity director, guide, facilitator, and motivator. In the lesson of the CAR Cycle I, Suriya designed the learning activity, posed questions for discussions, guided students how to answer the questions, and helped them to revise their answers. In his reflection, Suriya simply wrote, “My roles are as an activity director and an assistant” (Suriya’s reflection #4: November, 2008). In his lesson of the CAR Cycle II, Suriya motivated students’ interest and posed scientifically oriented questions. In this lesson, he diminished his role as an activity director. Suriya asked students to design the investigation, make decisions about the data they wanted to collect, and develop a method suitable for collecting and presenting their data. He guided students how to design the investigation and choose data collection method as well as the presentation format, as illustrated in an excerpt below.

Suriya:	What’re we going to survey?
Students:	Living things and non-living things.
Suriya:	How should we collect the data? Discuss with your peers in groups how to record the data . . . Time up! Now we’re going to present plans to collect data. Which groups want to speak first?
Student:	(A representative of a group stands up.)
Suriya:	Everybody listen to this group. If you haven’t got any ideas, you might get some from them . . .
Student:	(The student reports her group’s plan.)
Suriya:	(Suriya asks other groups of students.) How does this group count the animals if there are so many?
Students:	Estimate/Count their nests or flocks . . . What will you do after counting the animals? What will you do with the number?
Students:	Fill it in on the table.

Suriya: What does your table look like?

Student: (Student draws the table on the board.)

Suriya: Ok, other groups look at this table. If you have tables that are different from this group and want to share, you're welcome. . .

Suriya: Look at this table. Do you think the head of the table is clear enough?

Students: No, it isn't clear.

Suriya: No, it isn't. You might use this one when you collect the data. But you have to make it is understandable when you present the data. What should we do to make it better? Should we divide the head's column?

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

In the classroom of the CAR Cycle III, Suriya designed the learning activities, motivated students' interest, posed questions, guided students how to do the activities, and prepared learning materials for them.

The Role of the Student: Students should be active and minds-on investigators; whereas, in practice students are passive investigators.

Unlike Phichit and Monsid, prior to the CAR Program, Suriya already believed that the role of the student was that of an active and minds-on investigator. For Suriya, an active and minds-on investigator referred to those who did investigations with enthusiasm, shared ideas in discussions, posed experimental questions, formulated hypotheses, conducted experiments, analyzed data, made conclusions, and wrote reports. After Suriya experienced the professional development program, he maintained his initial understanding regarding the student role.

After Suriya experienced the first and second cycle of collaborative action research [CAR Cycle II], he still believed that the role of the student was active and minds-on investigator, as evidenced in his response during the third interview. Suriya stated, "Students were the leaders of the activity. They designed the survey. Students chose the data they wanted to observe and collect. They did the survey and presented their data. I didn't force them to do this activity" (Suriya's interview #3: January, 2009).

In the last cycle of the professional development program, the data from Suriya's lesson plan showed that he held the same idea regarding the student's role. In the lesson plan, Suriya planned to provide the guiding questions. He wanted students to address the questions by a discussion of environmental problems in their community. However, these questions only asked for students' opinions rather than their scientific reasoning. To answer the questions, students did not conduct any scientific investigation or review information from reliable resources to support their answers. Nevertheless, the data suggested that Suriya recognized that students should understand the purpose of doing an investigation, even though he had difficulty in generating scientifically oriented questions.

With regard to Suriya's teaching practice before and after the professional development program, the findings revealed that his practice was not compliant with his understanding. Before the CAR program, even though Suriya believed that students should assume roles as active and minds-on investigators, in practice, the students were passive investigators. Similarly, in his teachings after the CAR Program, students mainly took the role of passive investigator, except the lesson of the CAR Cycle II where students played the role of active and minds-on investigator. These findings are illustrated in more detail in what follows.

In the CAR Cycle I, students learned the lesson through discussion. They were asked to share their knowledge regarding the whole concepts in the Genetic Learning Unit. However, the majority of students did not get involved the activity. They occasionally shared ideas in discussions. Likewise, in the lesson of the CAR Cycle III, students took the role of passive investigators. In this lesson, they were assigned to complete two similar activities. Both activities required students to answer the same opinion-type questions. In the first activity, students observed pictures of environmental problems and answered four questions. In the second activity, they were asked to take/draw pictures of environmental problems in their community and bring these to the class. However, none of the students did the assignment. Suriya then adjusted the activity by using his own pictures. During discussion of both activities, students rarely shared their thoughts. Suriya had to "force" students to answer his questions, as evidenced below.

Suriya:	What are the problems in these pictures?
Students:	Factory releases waste water into the river.
Suriya:	(Suriya writes the answer on the blackboard.)
Students:	The problem is human.
Suriya:	Please specify the problem. Humans do what? Each group should answer at least one problem.
Students:	(Silent.)
Suriya:	Whoever answers quickly will get a bonus score.
Students:	Air pollution.
Suriya:	What else?
Students:	(Silent.)
Suriya:	Who did not answer? Each group has to give me one answer.
Suriya:	(Suriya points out one group.) Did you answer?
Students:	(Silent.)
Suriya:	Don't know yet. How about the next group?
Students:	(Silent.)
Suriya:	Don't have an agreement yet. Ok, next group?
Students:	The problem is human's need.
Suriya:	Please identify problem in the picture.
Students:	(Silent.)
Suriya:	What about the last group?
Students:	Cargo boats release oil into the sea.

(Suriya's classroom observation #6: February, 2009)

In Suriya's lesson of the CAR Cycle II, unlike the two lessons above, students played the role of active and minds-on investigators. Students worked in groups to design the survey, select the survey area, and develop the data table. They communicated their ideas about the data they wanted to collect and the instrument suitable for collecting the data. Students did the survey and presented their data to others. Students also knew scientifically oriented questions that the survey were expected to answer.

Instructional Objective: Teacher aims to develop students' scientific knowledge, science process skills, and scientific attitudes.

Initially, Suriya believed in teaching science through inquiry he should emphasize learning science content knowledge and science process skills. Similar to Phichit and Monsid, after Suriya experienced the professional development program, he extended his understanding regarding the instructional objective. Suriya recognized that the aims of science teaching and learning included not only scientific knowledge and process skills, but also scientific attitudes.

After experiencing the first cycle of collaborative action research [CAR Cycle I], the data from his inquiry-based lesson plan and interview revealed that Suriya did not focus his lesson on science process skills and scientific attitudes even though he understood the idea. In the lesson, Suriya wanted students to learn only knowledge. Suriya explained, "I know I should teach science by covering not only knowledge. But for this lesson I just want students to summarize all the ideas of the unit. So, the lesson does not involve process skills and attitudes" (Suriya's interview #2: November 2008).

The data from his lesson plans of the CAR Cycle II and the CAR Cycle III showed that Suriya focused his inquiry-based lessons on scientific knowledge, science process skills, and scientific attitudes compliant with the NSCS. With regard to scientific knowledge, Suriya wanted students to understand the terms environment, community, habitat, and ecosystem; to describe environmental features of the survey area; to explain causes of environmental problems; and to suggest solutions for minimizing the problems. For science process skills, he wanted students to design a survey, to select format suitable for collecting and presenting their data, to survey an ecosystem in the school's area, and to survey environmental problems in their community. In terms of scientific attitudes, students were expected to work collaboratively with others in groups.

With regard to Suriya's teaching practice, the research findings suggested that Suriya's practice agreed with his understanding both before and after the CAR Program. In his classroom practice for the CAR Cycle I, Suriya helped students to achieve the learning objective by posing questions, encouraging students to share ideas in discussions, and checking or revising the students' answers. In his teaching of the lessons in the CAR Cycle II and the CAR Cycle III, Suriya provided activities for students to learn about the physical environment, biological environment, community, ecosystem, environmental problems, and causes and solutions to environmental problems. Through the learning activities, students had the chance to practice several skills including observation, measurement, using numbers, data organization, and communication. To addresse the goal of teaching scientific attitudes, Suriya assigned students to work with others in small groups (3-4 students).

Instructional Process

Classroom Lesson Introduction: Teacher begins an inquiry-based lesson by motivating students' curiosity and clarifying the main question.

Prior to the CAR Program, Suriya understood that he should introduce an inquiry-based lesson by motivating students' interest and clarifying the main question. After he participated in the professional development program, Suriya still held the same understanding regarding classroom lesson introduction. Unlike Phichit and Monsid, Suriya did not recognize that he should also elicit students' prior knowledge.

After Suriya experienced the first cycle of the professional development program, the findings indicated that Suriya did not gain new understanding regarding the classroom lesson introduction in IBI. As Suriya stated:

> I know normally students should be interested in the lesson. But, in this lesson I don't expect their interests. So, I didn't prepare any activity to motivate them. But, I don't see the problem because students already studied the concepts we talked about. I just want them to review all the concepts [of the Genetics Learning Unit] before we begin a new unit. (Suriya's interview #2: November, 2008)

In addition, the data from his lesson plan showed that the questions Suriya used in the lesson were not scientifically oriented. They were general questions that relied on students' personal understanding and didn't require they provided evidence from investigations or reliable resources for support.

During the second meeting of the CAR Team, the data indicated that Suriya realized he did not plan his inquiry-based lesson by following the essential features of IBI, as evidenced in an excerpt below.

> After I talked with [the researcher] I thought that I should revise this lesson. There were too many concepts that I wanted students to gain in one lesson. By listening to the conversation in this meeting I also realized that my lesson did not represent the inquiry process. It was because I aimed to use this lesson for summarizing the full set of concepts in the genetic unit. (Activity I, central meeting #2: December, 2008)

After the second meeting, the findings revealed that Suriya began to recognize that to teach science through inquiry he should begin the lesson by motivating students' interest and making it clear for students the questions he wanted them to address, as evidenced in his lesson plan. Suriya planned to show pictures of an ecosystem and discuss these with students. He then provided them with scientifically oriented questions, which were, "Do different ecosystems have different kinds of living organisms? How and why are they different?" Suriya wanted students to address the questions by conducting a survey. The data from the group discussion during the third meeting reflected that Suriya understood that he should began the inquiry process with motivating students' interest, as evidenced previously in the section of the teacher role.

The data from his lesson plan of the CAR Cycle III reflected that Suriya maintained his initial understanding in that he should motivate students' interest and have a central question to investigate. In his lesson plans for the CAR Cycle II and the CAR Cycle III, Suriya planned to motivate students' interest by using pictures and discussions. After that, he assigned students four questions to answer including: what the problems in the pictures were, what the causes of the problems were, what solutions for solving the problems were, and who should be responsible for the problems. However, these questions did not require scientific responses. Students used only their opinions to address the questions.

With regard to Suriya's teaching practice before participating in the CAR Program, the findings revealed that there was an inconsistency between his understanding and practice. Suriya knew that he should motivate students' interest and clarify a main question to investigate. However in practice, besides motivation and stating the main question, Suriya also explained the concepts of study before asking students to do investigations. However, after Suriya experienced the CAR Program, the findings showed that Suriya's teaching practice aligned with his understanding. For instance, in the lesson of the CAR Cycle II, after the motivational activity, Suriya posed a scientifically oriented question. He then asked students to predict the answer, as shown in an excerpt below.

Suriya: The next question is, "Do different areas have different/the same kinds of living things? How and why are they different/the same?"

Students: It should be different.

Suriya: Why?

Students: Because the environment is different.

Suriya: Could you explain more?

Students: Animals like to live in different environments.

Suriya:	How about the other groups? What do you think? Do you agree or disagree with this group?
Students:	Agree.
Suriya:	So, your prediction is "different areas have different kinds of animals because the animals like to live in different environments."

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

Investigation: Students learn science by doing hands-on investigations devised by students or the teacher.

Initially, Suriya believed that students should be the ones who design and conduct hands-on investigations. After he engaged in the professional development program, Suriya still maintained his initial understanding that students should be responsible for these duties. However, in the last cycle of the CAR Program, it seemed like Suriya began to accept that the investigation could be developed by the teacher as well. Suriya's notion of students as the ones who devised the investigation is evident below.

Suriya:	I'm wondering if it should be easy to teach 9th grade because students have learned the process of inquiry when they were in 7th and 8th grades. So, when I put the equipment on their desks, students should be able to do the leaning activity. They should be able to think of how to do the activity. I should give them only advice. But, in fact, they can't.
Monsid:	For me, 9th grade is much more difficult.
Suriya:	It seemed like I have to teach them all, starting from what science is. I feel it's too heavy for me.
Educator:	I think you shouldn't expect too much. We should think we can teach whatever grade they are . . .
Phichit:	Yes, I agree. I teach 7th grade and also 8th grade. But when they move to 9th grade, I also have to teach them the same things.

Suriya: Hm. . . Even though we're talking, I still believe the thing I did was good. I gave them freedom to think.

Educator: Students can have freedom, but at the same time, you should provide them a framework. It's difficult for students to study without any direction, particularly students in schools participating in the EOLS.

(Central meeting #3: January, 2009)

After attending the first central meeting, Suriya's inquiry-based lesson plan and interview reflected that he did not plan to have students learn the lesson through scientific investigation. He wanted students to summarize the full set of concepts in a learning unit through discussion. Students used only their knowledge to answer the questions. As Suriya explained, "I think students already knew the concepts. When they listen to my questions, they should be able to answer the questions. I don't expect them to provide complete answers. But, I want students to review their understandings" (Suriya's interview #2: November, 2008).

After attending the second meeting with the CAR Team, the data from lesson plan and team meeting showed that Suriya had a better understanding regarding scientific investigation. Suriya planned to have students address scientifically oriented questions by doing a survey. As Suriya stated:

> . . . In this lesson, students planned the survey. They think of where they were going to survey, what they were going to collect, and how to collect the data. As usual, I provided them freedom to think. Students talked with friends in groups. After that, I asked them to present their plan to others . . . if their designs were not good, I asked the others to advise and adjust until I felt it was ok. In the third period, we then conducted the survey . . . (Central meeting #3: January 2009)

In the CAR Cycle III, the lesson plan data showed that Suriya began to accept that the teacher could also develop an investigation for students. In this lesson plan, Suriya designed the investigation for students.

With regard to Suriya's teaching practice before the CAR Program, the findings revealed that his practice partially complied with his understanding. Prior to the professional development experience, Suriya had students conduct investigation. However, the investigations were designed only by the teacher. However, after the CAR Program, Suriya's practice was aligned with his understanding, as evidenced in his instruction for the CAR Cycle II below.

Suriya:	Now, I want you to select your survey area, one area for a group. Where do you want to survey?
Group one:	Around the pond.
Group two:	The area around the flagpole.
Suriya:	. . . The next step is how do you want to survey?
Students:	Observe the area and collect some animals as a sample.
Students:	Observe and take pictures.
Suriya:	At first, you should think about the data you want to collect. What data do you want?
Students:	Living things and non-living things.
Suriya:	Yes, you may observe and record the living things you see. Count their numbers. How's about the data of non-living things?
Students:	Air temperature.
Suriya:	Which instrument could you use?
Students:	Thermometer.
Suriya:	What else do you need for your survey?
Students:	Magnifying glass . . .
Suriya:	Now, I want each group to write your plan. The plan should include, for example, the area you want to observe, data you want to collect, how to collect the data, how to present the data,

and the instruments you will use. Write the report step by step of how you are going to do the survey.

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

Conclusion/Explanation: Students should be responsible for analyzing data and formulating conclusions.

Similar with Phichit and Monsid, prior to the professional development program, Suriya understood that students should be responsible for analyzing data and formulating conclusions. However, Suriya did not know that he should link the conclusions to students' prior knowledge. After participating in the CAR Program, Suriya maintained his initial understanding that students were the ones who analyzed data and made conclusions. However, his understanding regarding prior knowledge was changed. Suriya began to conceive that he should link the new knowledge with students' prior knowledge.

After attending the first cycle of collaborative action research, Suriya still perceived that students were the ones who analyzed data and formulated conclusions. As Suriya stated, "I think students analyzed data from the textbook because the book didn't provide exactly the right answer. Students had to read and think about which part of the information was suitable to answer my questions. I then checked their answers" (Suriya's interview #2: November 2008). However, the data from lesson plan revealed that Suriya did not plan to have students collect and analyze data from the textbook. He wanted students to share their knowledge that they had learned from the last unit through discussion. In addition, Suriya did not intend to link the answers to students' prior knowledge.

After experiencing the second cycle of collaborative action research, Suriya held the same understanding that students were the ones who analyzed data and made conclusions. However, it seemed like Suriya began to understand the notion of linking new knowledge with prior knowledge, as evidenced in the discussion during the second meeting below.

Researcher: I agree with you that we may move this activity to the last stage, but only when students already have prior knowledge regarding pillbugs.

Monsid: I think we should have students observe the real pillbugs at first. We can move the first activity to the last stage or cut it out.

Phichit: I think we can keep the first activity but I think it's better to have students observe pillbugs in the first period.

Suriya: Let me clarify; in this point I think the aim of the first activity is to elicit students' prior knowledge while the observation in the activity aims to have students learn the concept. After that, we have students compare between what they initially understand with the knowledge they learn from the observation. So, if we cut the first activity, it means we don't have any information about students' prior knowledge.

Phichit: I see, so we couldn't connect between the new knowledge and prior knowledge.

Suriya: Yep.

Monsid: So, we use the first activity to assess students' prior knowledge, correct?

Suriya: It isn't really teachers assessing students. But, we want the information to have students assess themselves. To have students compare their current knowledge and their new knowledge. By doing so, students are able to see whether or not their prior understanding is correct.

Monsid: I see. Even though I see, I still want to cut it out because it looks complicated.

(Activity II, central meeting #2: December2008)

His response during the second interview showed that Suriya believed students were the ones who analyzed data and made conclusions. As Suriya stated, "I think students were those who analyzed data. I helped them by leading discussions. The questions used in discussions guided them to conclusions. If students could connect their answers, they would see the conclusions" (Suriya's interview #3: January, 2009). The data from lesson plan supported that Suriya planned to have students present their data. He then planed to discuss the data with students in order to guide them to analyze the data and formulate conclusions. After that, Suriya planned to connect the conclusions with related science concepts as well as students' prior knowledge.

After participating in the last cycle of collaborative action research, the findings showed that Suriya did not plan to have students collect and analyze data as well as make a conclusion in his lesson. Suriya's decision regarding the design of lesson plan seemed to be impacted by his constraint regarding time, as illustrated in an excerpt below.

Researcher:	What was the data students collected in the first activity?
Suriya:	No, in the first activity students did not collect any data. I just wanted to prepare them for the next activity.
Researcher:	It seemed like students only share their ideas, correct?
Suriya:	Yes.
Researcher:	Ok how about the second activity. What was the data they gathered?
Suriya:	I just told them to observe an environmental problem in their community and then bring the problems to the class for discussion. We shared ideas regarding how to deal with the problems. Actually, students have to create a science project for solving the problems, but it isn't in this lesson. I don't have time to do it in this semester. So, we just discussed and shared ideas. I did not ask students to analyze data or generate conclusions.

(Suriya's interview #4: February 2009)

With regard to Suriya's teaching practice, the results indicated that the teacher's teaching practice before the CAR Program did not agree with his understanding. Prior to the CAR Program, Suriya thought should be the one who analyze data and formulate conclusion. However, in practice, he and students analyzed data and made conclusions together in two lessons. After the CAR Program, Suriya's teaching practice was aligned with his lesson plans. Suriya and students analyzed data together in one lesson. There were no data analysis and conclusions in his two lessons. In his teaching practice of the CAR Cycle II, Suriya helped students to analyze data and formulate a conclusion by leading the discussion, as shown in an excerpt below.

Suriya:	Are you ready? Today, we're going to present the data that you gathered from the survey. Which group wants to come first? I'll give a bonus point for the first group.
Students:	In our group, we surveyed the area in front of building A. The weather was comfortable. The air temperature was 32 degrees . . . (Students wrote their data on the board.)
Suriya:	Time for the next group. A bonus point for the second group, too. Come quickly!
Students:	Our group surveyed the garden in front of the dean's office . . . (Students recorded their data on the board.)
Suriya:	Now, everybody look at the data of these three groups. Do you think their data is correct? . . . when you see the data of these groups and your data, could you tell me if survey area affects type and number of living things you found?
Students:	(Silent.)
Suriya:	The question might be too long. When comparing the data of the three groups, do they have the same data?
Students:	No, their data is different.
Suriya:	What are the differences in their data?
Students:	Number of living things, kinds of living things, water temperature, and air temperature.
Suriya:	Could we conclude that there are different kinds and number of living things in different areas?
Students:	No, there were some animals found in all three areas.

Suriya: So, how should we conclude this study? Could we conclude that there are different kinds and number of animals in different areas; however, there are some kinds of animals found in many areas?

Students: Yes.

Suriya: Do you know the reason that some animals could live in many areas while some live in a specific area?

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

Communication: Students share their data and conclusions with others.

Initially, Suriya understood that students should communicate data and conclusions with other students. After engaging in the professional development program, Suriya held the same understanding.

After experiencing the first cycle of collaborative action research, Suriya maintained his initial understanding that students should communicate their data and conclusions to others. Although Suriya did not plan to have students' collect data and formulate a conclusion in the first lesson, he wanted students to share their knowledge and answer his questions through discussion.

After completing the second and third cycles of collaborative action research, Suriya still understood that students should have chances to communicate their data and conclusions with others. The data from his lesson plan of the CAR Cycle II showed that Suriya wanted students to share their data and conclusions. In the third lesson, even though Suriya did not have students collect data, his response during the last interview reflected that he wanted students to justify and evaluate their understanding with each other, as illustrated in the excerpt below.

Researcher: Did you have students communicate their data and conclusions in this lesson?

Suriya: Yes, I did. But, practically, students did not communicate much in this lesson.

Researcher: Why do you think they did not communicate?

Suriya: Because students just talked to me, and answered my questions. They did not consult with their colleagues in their groups. Students did not brainstorm and exchange ideas to answer my questions. I did not see students talk to each other in that way.

(Suriya's interview #4: February, 2009)

The results indicated that prior to the professional development experience, Suriya's practice was in agreement with his understanding. In practice, Suriya had students communicate their data and conclusions in two lessons. After he engaged in the CAR Program, his teaching practice continued to be aligned with his understanding. In his classroom teaching of the CAR Cycle II, students communicated their data and conclusions through written presentations and whole class discussions. By doing so, students had opportunities to justify and evaluate their data and conclusions with other alternative conclusions. In the CAR Cycle I and the CAR Cycle III, there were no data and conclusions in the lessons. However, Suriya provided students chances to share their ideas and evaluate their understanding with other students.

Group Work: Students learn science in groups.

Initially, Suriya understood that students should learn science in groups. Suriya thought to learn in groups, students should help each others to complete the group's work. After he engaged in the CAR Program, Suriya held the same understanding regarding group work.

After completing the first cycle of collaborative action research, the findings suggested that Suriya held the same understanding regarding group work. His response during the second interview showed that Suriya knew that students should learn in groups even though he did not plan to have them learn in groups in the lesson.

As Suriya stated, "In this lesson, I did not assign students to work in groups. But, students couldn't answer my questions. They then had to find information from the textbook and there were only some students in the class that had textbooks. So, it seemed like students learned in groups" (Suriya's interview #2: November 2008).

After experiencing the second and third cycles of collaborative action research, Suriya maintained his initial understanding that he should provide the opportunity for students to learn in groups, as illustrated in the team discussion of the third meeting below.

Suriya: I had students learn in groups. Each group had 3-4 members. Individual members had a specific role and duty. I guided them at the beginning of the semester about their roles and duties. However, in the past, the achievement of group work was low because students tended to sit with the ones they believed were better than them. So, finally students that no one wanted stayed in the same group and got nothing throughout the school year. So, I solved the problem by grouping students according to their number. So, they were randomly clustered into groups.

Educator: May I suggest something? I think you should group students by yourself because you know them the most. But, you don't tell them that you want to mix their abilities . . .

Monsid: I used to do this once. It could help to support students' spirit. I told students a story about a rabbit and a hunter . . . the point is to encourage them to work with new environments or to be adaptable. In this case, I want students to work with a new group's members.

(Central meeting #3: January 2009)

Suriya's response during the last interview supported that he wanted students to learn in groups and he believed that small groups could encourage students to participate in the learning activity better than large groups. As Suriya stated:

> I assigned students to learn in groups in this lesson. Students were free to choose their group's members. However, each group must have at most 4 persons. In the past, I used to have 6-7 students in a group. But, I found many students did not do their work. So, I limited each group to have 3-4 members. I hoped it would help them to engage in the activity . . . Students might regroup if they want. I wasn't strict that they had to work with the same group throughout the semester. It's up to them. But, basically students didn't change groups. They liked to work with ones they were intimate with. (Suriya's interview #4: February, 2009)

With regard to Suriya's teaching practice, the findings indicated that his practice before the CAR Program was not consistent with his understanding. In practice, even though students sat in groups, they learned as individuals. However, Suriya's teaching practice after the CAR Program aligned with his understanding. In his classroom teaching for the CAR Cycle II and the CAR Cycle III, Suriya promoted cooperative group work by having students work in small groups, assigning roles and duties for individual members as well as encouraging students to consult with their peers in groups. As Suriya stated, "Before answering my question, you should work in groups. Brainstorm your ideas with friends. Don't think alone. That's why we learn in groups" (Suriya's classroom observation #6: February 2009).

Common Findings

The Role of the Teacher: Teacher has multiple roles.

The findings across the three teachers revealed that, for the most part, the teachers' understandings were consistent with their practices. Both teachers' understandings and practices were developed, more or less, from their initial understandings and existing practices. After the CAR Program, all three teachers conceived that the teacher role was multiple. Their understandings and practices seemed to shift to a more learner-directed inquiry. However, the three teachers developed their understandings and practices at different points of the professional development experience. For Phichit, he began to view the role of the teacher as multiple after engaging in the first cycle of collaborative action research. In the case of Suriya, he came to accept the new role in the second cycle. Monsid held this notion before he participated in the CAR Program and maintained the same understanding throughout the professional development program.

The Role of the Student: Students are active and minds-on investigators.

The findings across the three teachers revealed that there was a consistency between Phichit's and Monsid's understandings and their practices with regard to the role of the student. However, in the case of Suriya, for most part, his understanding was not compliant with his practice. In general, the three teachers' understandings and practices were changed from their initial understandings and existing practices. All three teachers consistently agreed that the role of the students in an inquiry-based classroom was as an active and minds-on investigator. However, their practices varied. In Phichit's and Monsid's lessons, students played the role of active and minds-on investigators while in Suriya's classrooms, for the most part, students took the role of passive investigators. More specifically, the development of the three teachers' understandings and practices shifted into a more learner-directed inquiry.

The findings revealed that the three teachers came to change their understandings and practices at different points of the CAR Program. For Phichit, he began to conceptualize the role of student as active and minds-on investigator after completing the first cycle of collaborative action research. According to Monsid, he came to accept the notion after engaging in the second cycle of collaborative action research. For Suriya, he conceived the idea prior to his participation in the CAR Program. His practice was developed after completing the first cycle of collaborative action research. However, in Suriya's final lesson students were not provided with the opportunity to be active, minds-on investigators.

Instructional Objective: Teachers aim to develop students' scientific knowledge, science process skills, and scientific attitudes.

The findings from the three teachers revealed that, for most part, the teachers' teaching practices aligned with their understandings about instructional objectives. In general, the results showed that the three teachers' understandings and practices regarding the instructional objectives were broadened. After experiencing the first cycle of collaborative action research, the three teachers recognized that they should focus their lessons on scientific knowledge, science process skills, and scientific attitudes. The teachers' development was compliant with the goal of science teaching and learning in the NSCS. The new understandings and practices regarding the instructional objective of all teachers were maintained throughout the last three phases of the CAR Program.

Instructional Process

Classroom Lesson Introduction: Teachers begin an inquiry-based lesson by motivating students' curiosity and clarifying a scientifically oriented question.

The findings across the three case study teachers showed that the teachers' teaching practices agreed with their understandings. In particular, the three teachers' understandings and practices regarding classroom lesson introduction after the CAR Program were developed from their initial understandings and existing practices. All three teachers consistently agreed that it was important to motivate students' interest in the concept being focused upon and clarify the questions in which students were expected to answer. However, only Phichit and Monsid recognized that they should also elicit students' prior knowledge.

The findings revealed that the three teachers began to change their understandings and practices at different points of the CAR Program. Phichit and Monsid, they began to change their views of clarifying scientifically oriented question and eliciting students' prior knowledge after attending the first cycle of collaborative action research. Suriya came to accept the idea of eliciting students' prior knowledge after he engaged in the second central meeting with the CAR Team.

Investigation: Students learn science by doing hands-on investigations.

The findings across the three case study teachers showed that, in general, the three teachers' practices aligned with their understandings. Their understandings and practices about the design and conduct of classroom investigations after the CAR Program were somewhat developed from their prior understandings and existing practices. All three teachers agreed that students should learn science through hands-on activities. However, the teachers held differing notions regarding who should devise the investigation. Phichit and Monsid accepted that the investigation could be designed by the teacher, students, or both. Suriya thought the investigation should be designed by students or the teacher. However, in practice, Monsid designed the investigations in his three lessons. For Phichit and Suriya, students were given the chance to design the investigation in one lesson. The findings also showed that the three teachers began to develop their understandings and practices at different points of the professional development program. Monsid began to conceptualize the notion of using various methods of scientific investigation after attending the first cycle of collaborative action research. According to Suriya, he came to conceive the idea of hands-on, scientific investigation after attending the third meeting with the CAR Team. Phichit held the concept of hands-on, scientific investigation before engaging in the CAR Program.

Conclusion/Explanation: Students are responsible for analyzing data and formulating conclusions.

The findings across the three teachers indicated that Monsid's and Suriya's teaching practices were not in agreement with their understandings whilst Phichit's teaching practices aligned with his understandings. For the most part, all three teachers maintained their understandings that students should take an active role for analyzing data and formulating conclusions. However, the three teachers were different in their practices. In Phichit lessons, students had the chance to analyze data and formulate conclusions on their own. In Monsid's classes, he and students analyzed data and formulated conclusions together. Based for Suriya, he and students analyzed data and formulated conclusions together in only one of three lessons. With regard to students' prior knowledge, the three teachers accepted that they should link the new knowledge learned from investigations with students' prior knowledge. Nevertheless, in practice, the three teachers connected the new knowledge with students' prior knowledge in only one lesson per teacher.

The findings revealed that the three teachers began to develop their understandings and practices, particularly in terms of connecting new knowledge with prior knowledge, at different points of the CAR Program. For Phichit, he began to conceive the idea after experiencing the first cycle of collaborative action research. According to Monsid, he accepted the notion after completing the third cycle of collaborative action research. For Suriya, he began to conceive the idea after he engaged in the second meeting.

Communication: Students have chances to share their data and conclusions with others.

The findings across the three case study teachers showed that all of the teachers maintained their understanding in that students should share their data and conclusions with others. The aim of the sharing was to provide students chances to evaluate and justify their data and conclusions with the other groups of students. In addition, for Phichit, the communication also helped students to learn to listen to and accept other people's opinions. In general, the three teachers' teaching practices were in agreement with their understanding. Students in the classrooms of the three teachers had chances to communicate their data and conclusions with other students. However, in Suriya's classroom instruction, there were two lessons that students did not have opportunities to justify and evaluate their conclusions with alternative ones since there was no data collection in these lessons.

When comparing the level of the three teachers' development of their understandings and practices concerning aspects in the instructional process (from lesson introduction to communication), the findings indicated that Phichit tended to design his lessons to be more learner-directed inquiry while Monsid's lessons were to be more teacher-directed inquiry. However, for Suriya's lesson, it seemed like he wanted to have less control on the lesson. But, in practice, Suriya still had more control in his lessons. In addition, the findings reported that Suriya confronted difficulty in generating scientifically oriented questions.

Group Work: Students learn science in groups.

The findings across the three case study teachers revealed that, in general, the teachers' teaching practices were consistent with their understandings. The teachers' understandings and practices were somewhat developed from their initial understandings and existing practices. After having the professional development experience, the three teachers all agreed that they should have students learn science in groups. In practice, all three teachers promoted, more or less, students' learning through cooperative group work. The findings also indicated that the three teachers began to improve their understandings and practices regarding group work at different stages during the professional development program. For Phichit, his understanding was broadened after completing the second cycle of collaborative action research. Monsid began to conceptualize the idea after experiencing the first cycle of collaborative action research. According to Suriya, he accepted the notion after engaging in the last cycle of the CAR Program.

Discussions in Relation to the Second Research Question

The discussions of the teachers' understandings and practices about particular aspects of the essential features of IBI are provided below.

Role of the Teacher and Role of the Students

After experiencing the professional development program, Phichit, Monsid, and Suriya each developed their understandings and practices regarding the teacher's role and the student's role. The three teachers accepted that the role of the teacher in IBI was multiple. These roles included guide, motivator, facilitator, and activity director. This finding agreed with Dewey (1938 cited in Barrow, 2006) in that he thought the science teacher should play the roles of guide and facilitator. Dewey also pointed out that students should be enthusiastic in learning science. To promote students' attentiveness, Dewey suggested students should study problems or questions that related to their daily lives. With this in mind, teachers were considered to play a key role in motivating students' interest. The three teachers' understandings and practices also complied with the NSCS (DCID, 2002). According to the NSCS (DCID, 2002), science teachers should design learning activities that promote students to learn science through an inquiry process.

For the role of the student, after engaging in the CAR Program, all three teachers held a shared understanding that the student's role was active and minds-on investigator. For the three teachers, an active investigator was the one who conducted hands-on activities, analyzed data, generated conclusions, and participated in discussions. Minds-on investigator was similar to active investigator, with the addition that students knew a question that the investigation intended to answer, and thought critically and logically about the activities they engaged in. Their understandings were consistent with the NSES (NRC, 1996). According to the NSES (NRC, 1996), students must have both hands-on activities and minds-on experience. To ensure students experienced both hands-on and minds-on opportunities], the NSES (NRC, 1996) suggested students should describe objects and events, ask questions, construct explanations, test the explanations against current scientific knowledge, and communicate their understandings to others. They should also identify their assumptions, use critical and logical thinking, and consider alternative explanations. The teachers' understandings were also compliant with the NSCS (DCID, 2002) that specified that when engaging in inquiry, students would construct knowledge through several activities such as observing phenomena, posing question, and doing scientific investigation.

Instructional Objective

After having professional development experiences, all three teachers came to accept that they should emphasize their inquiry-based lessons on scientific knowledge, science process skills, and scientific attitudes consistent with the NSCS. Their understandings were in accordance with the NSCS (DCID, 2002). According to the NSCS (DCID, 2002), science teaching and learning aimed to develop students not only in science content knowledge but also science process skills and scientific attitudes. For the NSCS, learning activities in inquiry should develop learners in terms of logical thinking, designing and doing investigations, reviewing information from reliable resources, collecting and analyzing data, interacting with each other, formulating explanations based on evidence, answering problems or questions, and ultimately constructing knowledge. The teachers' understandings were also aligned with Dewey (1910) and Schwab (1960) in that they believed science should be taught as both subject-matter and the method for producing or discovering the subject-matter. As Dewey (1910: 124) wrote, ". . . science teaching had suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject-matter of fact and law, rather than as the effective method of inquiry into any subject-matter."

Instructional Process

After engaging in the CAR Program, the three teachers perceived that they should introduce inquiry-based lessons by motivating students' interest and clarifying problems or questions to investigate. Phichit and Monsid also knew that they should elicit students' prior knowledge of the concept being focused on. The teachers' understandings were consistent with the BSCS 5Es instructional model (Bybee *et al.*, 2006) and the 5Es inquiry process (DCID and IPST, 2002). Both science teaching models began with an engagement phase. In this phase, teacher used a short activity to promote students' curiosity and access students' prior knowledge. Teachers attempted to have students pose question or be interested in question provided by teacher. The three teachers' understandings were also compatible with one of the essential features of classroom inquiry defined by the NRC (2000). According to the NRC (2000), learners were engaged in inquiry-based classroom through scientifically oriented questions. The NRC (2000: 24) defined, "scientifically oriented questions are questions that lead themselves to empirical investigation, and lead to gathering and using data to develop explanations for scientific phenomena." The NRC also noted that the questions must be able to be addressed by students' observations and scientific knowledge gathered from reliable resources. However, the study showed that even after the CAR Program Suriya's teaching practice did not align with the constructivist perspective regarding the role of students' prior knowledge.

In terms of investigation, after the three case study teachers participated in the professional development program, all of them maintained their understanding that they should have students learn science through hands-on investigations. However, Monsid and Suriya began to broaden their notion regarding those who developed the investigations. Phichit and Monsid accepted that the investigations could be designed by the teacher, students, or both parties. For Suriya, he perceived it could be devised by the teacher or students. Monsid also extended his understanding regarding methods of scientific investigation. He perceived students could answer scientifically oriented questions through review of information from reliable sources and doing a survey. The three teachers' understanding aligned with the DCID and the IPST (2002). According to the DCID and the IPST (2002: 81), scientific investigation was defined as methods for acquiring scientific knowledge. These methods required students to collect data, think logically, formulate hypothesis (or prediction), interpret data, and generate explanations. The DCID and the IPST suggested that there were various methods of scientific investigation teachers could use in inquiry such as observation, survey, experimentation, and review of information from reliable sources. This understanding also corresponded with the NRC (2000). According to the NRC (2000), scientific investigation could be developed by teacher, students, or both parties, depending on the expected outcomes.

After receiving the professional development experiences, the three teachers maintained the same notion that students should be responsible for analyzing data and making conclusions. They also perceived that conclusions were generated based on data obtained from investigations. However, the three teachers began to conceive that they should link conclusions to students' prior knowledge. The three teachers' understanding aligned with the BSCS 5Es instructional model (Bybee *et al.*, 2006) and the 5Es inquiry process (DCID and IPST, 2002). In the explanation phase of the two teaching models, learners were encouraged to formulate conclusions/explanations based on evidence gathered from investigation and/or reliable resources. The teacher then probably explains the science concept, process skill, or attitude for learners. These explanations intended to guide students toward a deeper understanding of the concept, process skill, and attitude. This finding was also compliant with one of the essential features of classroom inquiry defined by the NRC (2000). According to the NRC (2000), learners formulated explanations from evidence to address scientifically oriented questions. The NRC described scientific explanations provided causes for effects and established relationships based on evidence and logical arguments. Thus the explanations must be consistent with investigational evidence. However, the research findings indicated even though the three teachers accepted the idea of connecting new knowledge with prior knowledge, in practice, they occasionally followed this understanding. Phichit and Monsid connected the conclusion with students' prior knowledge only in one lesson. In the case of Suriya, he did not relate new knowledge with students' prior knowledge in any of his lessons.

With regard to communication, after the CAR Program, the three teachers maintained their understanding in that students should share their data and conclusions with others. However, Phichit's understanding was broadened. He began to accept that communication was not only the way students learned to broaden their knowledge but it was also the way they learned to listen to and accept others' opinions (scientific attitude). The three teachers also incorporated this type of communication of results by students in their actual classrooms. The findings showed that, in practice, the three teachers tended to provide students opportunities to communicate their data and conclusions more than in their lessons before the CAR Program. The three teachers' understandings and practices were consistent with one of the essential features of classroom inquiry (NRC, 2000). According to the NRC (1996: 27), learners communicated and justified their explanations with others. The NRC indicated "sharing explanations provided others the opportunity to ask questions, examine evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations."

After Phichit, Monsid, and Suriya participated in the professional development program, the three teachers uniformly agreed that they should provide opportunities for students to learn science in groups. The three teachers believed cooperative group work occurred when all the group's members were part of their group's success. For Phichit and Monsid, they also conceptualized that students' knowledge was enriched when students interacted with each other in groups. Monsid and Suriya promoted cooperative group work by having students learn in small groups. Suriya also assigned roles and duties for individual students. The three teachers' understandings and practices aligned with the social constructivist's perspective in that individuals constructed meaning of what they experienced through interactions with each other (e.g., teachers and peers) and with the environment they lived in. Their understandings were also compliant with "positive interdependence" – one of five essential components of cooperative learning defined by Johnson and Johnson (1991: 55). Johnson and Johnson explained "positive interdependence" existed when individual group's members perceived they cannot succeed unless all their group's members did. Individual members must coordinate their efforts to complete a task. To promote positive interdependence, the authors suggested the teacher might assign individuals complementary roles. Monsid's and Suriya's notion also agreed with "individual accountability" – another one of the five essential components of cooperative learning (Johnson and Johnson, 1991). Johnson and Johnson (1991) indicated that one way for ensuring that each student was individually accountable was that the teacher helped groups avoid redundant efforts by members. The authors noted small size in each group might be an appropriate solution.

When comparing the time in which individual teachers began to develop their understandings and practices in relationship to the four aspects of the essential features of IBI, the findings indicated that Phichit seemed to develop most of the essential features of inquiry after experiencing the first cycle of the collaborative action research and maintained these new understandings and practices throughout the CAR Program. For Monsid and Suriya, the findings pointed out that the two teachers began to incorporate many of the key components of IBI after they completed the second cycle of the collaborative action research. For Monsid, the new understandings and practices were sustained in the third cycle of the collaborative action research. Unfortunately, for Suriya, a number of key features he demonstrated in his teaching after the second cycle were less evident in the third cycle of the CAR Program.

The fact that individual teachers were different in terms of the time it took to develop their skill with IBI and how they maintained their development may relate to the teachers' background. Phichit had received a scholarship from the Project for the PSMT and he just completed his master's degree in Science Education one year prior to the CAR Program. Thus, Phichit may have had more extensive or deeper content knowledge in science and he may have been familiar with scientific inquiry as an aspect of a pedagogical tool. Suriya's more limited development with regards to IBI may stem from the fact that he did not have strong content knowledge in biological science, as he mentioned earlier before engaging in the CAR Program. This factor may have impacted how he designed or selected the activity in his last inquiry-based lesson.

In summary, the findings showed that after the three case study teachers received professional development experiences from the CAR Program, their understandings and practices were broadened in all aspects of the essential features of IBI. These results suggested that the CAR Program was an effective professional development program for promoting the case study teachers in terms of understandings and practices of IBI.

CHAPTER VI

CONCLUSIONS AND IMPLICATIONS

Introduction

This chapter aims to provide the conclusions and implications of the research study. The chapter begins with a summary of the study. It is followed by the conclusions of the research results. The chapter is ultimately completed with the implications of this study for the educational community.

Research Summary

Research Aims

The present study is about lower secondary science teachers who participated in the teacher professional development program, entitled the collaborative action research program [CAR Program] in academic year 2008. The research study examined three teachers, Mr. Phichit, Mr. Monsid, and Mr. Suriya, professional growth and changes in terms of understanding and implementing IBI in their science classrooms. The three teachers' understandings and practices regarding IBI were tracked both before and after the teachers participated in the CAR Program. The study also considers efficacy of utilizing the CAR Program in promoting the teacher's understanding and practice of IBI in a real classroom context.

Research Questions

This study is shaped by the following research questions:

1. What are the Thai science teachers' understandings and practices of inquiry-based instruction before they engage in the collaborative action research program?

2. What are the Thai science teachers' understandings and practices of inquiry-based instruction after they engage in the collaborative action research program?

Review of Methodology

The methodology employed for investigating the change of teachers' understandings and practices about IBI is interpretive methodology which is framed by qualitative research. The method of the study is qualitative case study, which consists of three science teachers who taught at lower secondary level (7^{th}–9^{th} grades) in two schools participating in the Project for Extension Opportunity at Lower Secondary Level [EOLS Project]. The three teachers were purposefully selected based on the criteria of participants' willingness to be involved in the professional development program, their lack of opportunities to participate in other professional development programs/workshops in relation to IBI during the past three years, and their school's location which is located nearby the central meeting site (Faculty of Education). To capture any changes of individual teacher's understanding and practice about IBI before and after their involvement in the CAR Program, multiple sources of data were utilized. The data sources included individual interviews, teacher's inquiry-based lesson plans, teacher's written reflections on their teaching, classroom observations, and group meetings. The data was initially evaluated through a within-case analysis which was followed by a cross-case analysis. The results are reported in individual cases. It is followed by a discussion of common findings across the three cases. A brief description of the professional development program set out in this study is provided below.

The CAR Program: A Professional Development Program

Participating in this study provided the teachers with opportunities to improve their understandings and practices of IBI in the context of a professional development program, known as the collaborative action research program [CAR Program]. The CAR Program was designed to enhance Thai science teachers' understanding about IBI and practice of the approach in their actual classrooms. This program was characterized by the desirable features of a teacher professional development program in Thailand which include: a) having long-term support for teachers both in groups and as individuals, b) taking place in teachers' actual classroom, c) encouraging teachers to change their practice, d) being part of the teachers' regular duties, e) promoting collaboration between teachers and the program facilitator, f) empowering teachers' sense of ownership, g) requiring teachers' willingness, and h) working in a friendly atmosphere (Office of the Education Council, 2004; Puntumasen, 2004). The CAR Program design was based on action research (Kemmis and McTaggart, 1988, 2000; Zuber-Skerritt, 1991) and collaborative action research (Oja and Smulyan, 1989), which included: a) focus on practice, b) emphasis on professional development, c) self-reflection, d) democratic project leadership, e) time and support for opening communication, f) collaboration, and g) recurrence of the action-reflection cycle.

Participation in the CAR Program was intended to assist the three teachers in developing their understandings and practices about IBI by completing three cycles of collaborative action research (also referred to as the action-reflection cycle) and attending a number of meetings with the CAR Team, both in the central meeting site and in the teachers' schools. Prior to the first cycle of collaborative action research, the CAR Team members met once at the central meeting site. This meeting aimed to encourage the teachers' awareness of the significance of teaching science through IBI, to set up the essential features of IBI as a framework for the study, and to have the teachers learn IBI through the process of sharing and reflecting on their inquiry-based teaching experiences. After the first central meeting, there were three more central meetings of the CAR Team. These meetings were held separately, after the teachers completed each collaborative action research cycle. In each meeting, the teachers did the same thing; they brought their lesson plan, teaching experience, and problems regarding understandings and practices about IBI to share and reflect with the CAR Team. To work on each cycle of collaborative action research, individual teachers designed an inquiry-based lesson plan, implemented the lesson in his classroom, observed his teachings via videotape, and wrote a reflection on the teaching practices. The researcher assisted individual teachers through one-to-one meetings with the teacher in his school. A framework of the study is displayed in the Figure 6.1.

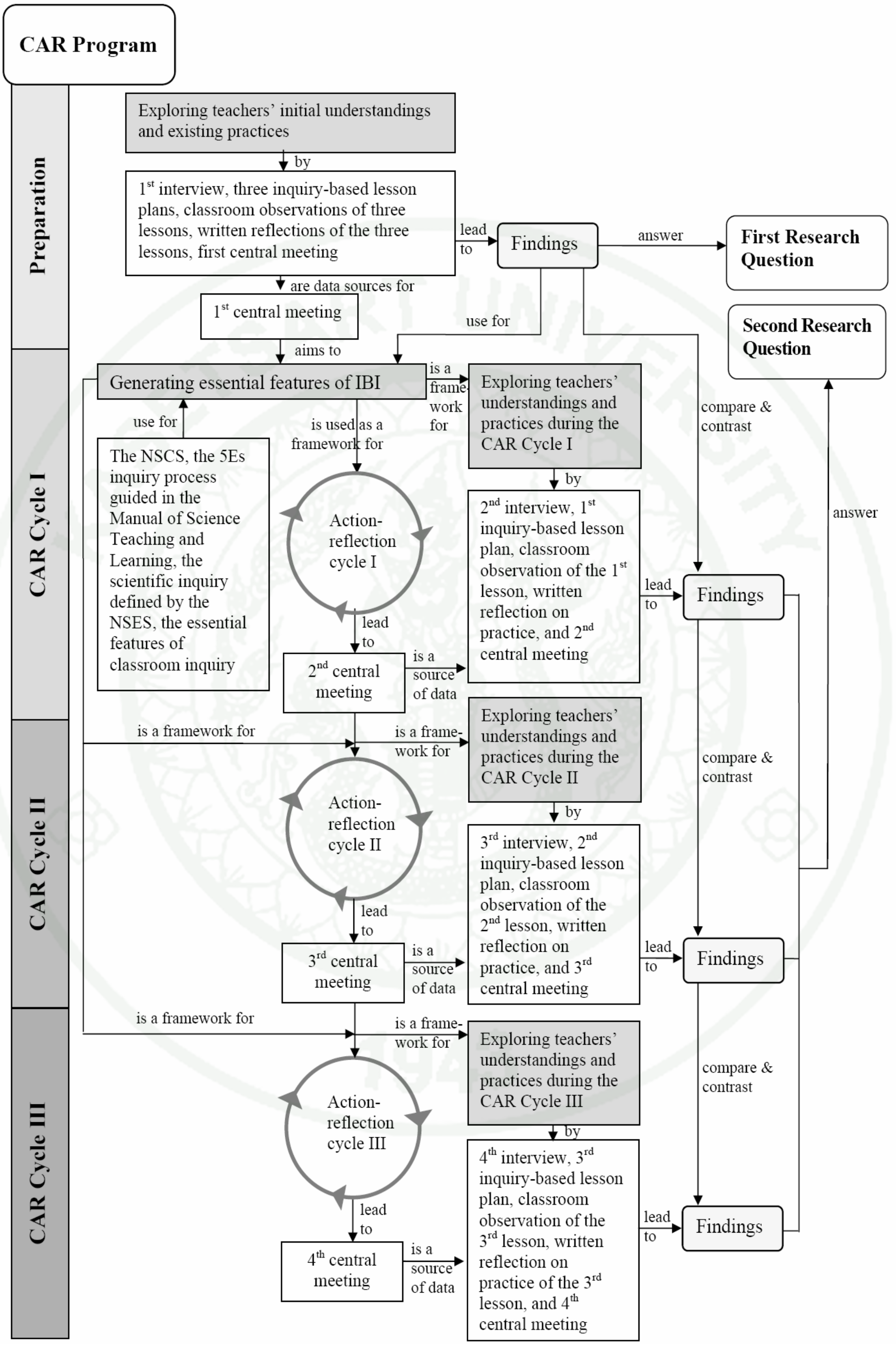

Figure 6.1 Framework of the Study

Conclusions of the Study

This section presents the conclusions of the research study, which are divided into two parts according to the two research questions:

Conclusions in Relation to the First Research Question

To address the first research question, inquiry-based instruction was considered in terms of what teachers understood and practiced about particular aspects of IBI prior to their participation in the professional development program. The findings were gathered from multiple sources of data including individual interview, inquiry-based lesson plans, written reflections, classroom observations, and central meeting. All of the data sources were collected during the Preparation phase of the study. The findings across the three case studies reveal that before the professional development experiences, the three teachers did not fully understand and implement student-directed inquiry in their science classrooms. In general, the teachers knew their role and their students' role in IBI consistent with the NSCS. For the instructional objective, the three teachers did not focus their inquiry-based lessons on scientific attitudes. The teachers focused their lessons only on scientific knowledge and science process skills.

Prior to participating in the CAR Program, the teachers' understandings and practices regarding instructional process were aligned with teacher-directed inquiry. The teachers' understandings and practices reflected a combination between the notions of confirmation activity (Tafoya *et al.* 1980 cited in Bell, 2002: 16) and structured inquiry (Colburn, 2000; DCID, 2002). According to Tafoya *et al.* (1980 cited in Bell, 2002), confirmation activity is referred to as a teacher-directed type of inquiry where the teacher provided questions, step by step procedures, and materials for learners. Learners were involved in activities in an effort to rediscover some identified phenomena. Similar with confirmation activity, structured inquiry is also a type of teacher-directed inquiry. In this regard, the teacher provides a question, hands-on investigation, and materials for learners (DCID, 2002). However, learners have chances to think logically, to select a method for recording data, and to analyze data. Colburn (2000) noted in structured inquiry teachers should not inform learners of investigational outcomes. Rather, they should allow learners to discover relationships between variables or formulate explanations on their own. The findings across the three teachers indicated that prior to taking part in the CAR Program; in practice the teachers had students conduct investigations by following their directions. Students learned the concepts from textbooks or their explanations before doing investigations. The investigations were used for rediscovering or verifying identified concepts. In many lessons, the teachers did not provide students the opportunity to communicate their conclusions with others. Students did not have opportunities to evaluate and justify their conclusions with alternative conclusions. Nevertheless, the teachers did provide students chances to think logically, to analyze data, and to formulate conclusions.

When comparing the teachers' understandings with their practices, the findings indicated that the teachers' instructional practice was somewhat different from their understandings. For the role of the teacher, the three teachers played more roles than they thought they played. With regard to the role of the student, students in Suriya's lessons played roles differently than he believed. As for classroom lesson introduction, all three teachers knew that they should introduce an inquiry-based lesson by motivating students' interest. However, in practice this didn't always happen. In terms of investigations, the three teachers conceived students should learn science through hands-on investigations, but in practice, the investigations were devised only by the teacher. For conclusions/explanations, the three teachers accepted that students should be responsible for analyzing data and making conclusions. However, in practice, the teachers typically formulated conclusions for students or had students make conclusions on their own without sharing their conclusions with others. For communication, all the teachers thought students should communicate both data and conclusions; however, in practice students presented only the data. In terms of group work, Phichit and Suriya knew that students should learn in groups. However, in practice, students sat together in groups, but did not work cooperatively.

When comparing the three teachers' understandings and practices with the essential features of IBI, the results showed that before they took part in CAR the teachers' understandings and practices agreed with a number of the essential features of IBI. For the teacher's role, all of the teachers' understandings and practices are compliant with the notion that the roles of the teacher are a guide and a motivator. In terms of the student's role, the three teachers' understandings correspond with the notion that the student role is that of an active investigator. With regard to instructional objective, the three teachers' understandings and practices are in agreement with the idea that students learn scientific knowledge and science process skills consistent with the NSCS. As for instructional process, the three teachers' understandings and practices are aligned with many essential features including: 1) inquiry process begins with motivating students' interest or curiosity, students conduct investigations, and collect data; 2) students, the teacher, or both design the investigation; 3) a scientifically oriented question is answered by a scientific investigation; 4) students, the teacher, or both parties analyze data gathered from investigation; and 5) students, the teacher, or both connect conclusions/explanations to scientific knowledge.

However, prior to participating in CAR the three teachers' understandings and practices were not fully compliant with the ideas that: 1) the role of student is minds-on investigator; 2) science teaching through IBI should also emphasize scientific attitudes; 3) the teacher should elicit students' prior knowledge and link conclusions to prior knowledge; 4) students should have a scientifically oriented question as a goal for doing investigations; 5) students communicate and justify their conclusion/explanation with other students; 6) students evaluate their conclusion/explanation in the light of alternative ones; and 7) students have a chance to learn through social interaction during group work.

Conclusions in Relation to the Second Research Question

To address the second research question, IBI was considered in terms of what the three case study teachers understood and practiced about particular aspects of IBI while they were in the context of the professional development program. Multiple sources of data were used to establish the results of the study. The data sources included individual interviews, inquiry-based lesson plans, written reflections, classroom observations, and central meetings. The data was collected during the three cycles of the collaborative action research of the CAR Program: CAR Cycle I, CAR Cycle II, and CAR Cycle III. The results found among the three case study teachers indicated that after receiving the professional development experiences, the three teachers had better understandings and practices about IBI than their initial notions and existing practices. In particular, the teachers' understandings and practices after participating in the CAR Program reflected a shift toward a more learner-directed type of inquiry. The three teachers held full understandings and practices about student-directed inquiry in terms of the role of the teacher, the role of the students, and the instructional objective. The three teachers accepted their role as multiple and the student's role as active and minds-on investigator. They realized that they needed to emphasize in their inquiry-based lessons the three elements of scientific knowledge, science process skills, and scientific attitudes.

With regard to instructional process, the teachers' understandings and practices moved back and forth among the notions of structured inquiry, guided inquiry, and open inquiry (Tafoya *et al.* 1980 cited in Bell, 2002; Colburn, 2000: DCID, 2002). According to the DCID (2002), structured inquiry was a type of inquiry where the teacher provided questions, hands-on investigations, and materials for learners. Nonetheless, learners have chances to think logically. For Tafoya *et al.* (1980 cited in Bell, 2002), guided inquiry referred to a less teacher-directed type of inquiry. In this type, the teacher provided only materials and questions to investigate whereas learners devised their own investigation to address the question (Tofoya *et al.* 1980 cited in Bell, 2002; Colburn, 2000). For Tafoya *et al.* (1980 cited in Bell, 2002), open inquiry was learner-centered. Both Tafoya *et al.* (1980 cited in Bell, 2002) and

Colburn (2000) point out that open inquiry had similarities with guided inquiry. The addition was that in this type of inquiry learners formulated their own problem or question to investigate. The teacher acted as a facilitator who provided learners with materials as needed. Colburn (2000) indicated open inquiry in many ways was parallel with doing science. For the DCID (2002), guided inquiry was characterized as having an open-ended problem to investigate while open inquiry was known as a science and technology project.

The findings across the three teachers indicated that, in practice, the scientifically oriented questions used in the teachers' lessons were generated by the teachers or students. During lesson introduction, the teachers had activities to promote students' interest. They provided students opportunities to design investigations in some lessons. Unlike what happened prior to the CAR program, the three teachers had students conduct investigations to build up their knowledge. They did not provide students with the concepts before doing investigations. Students were encouraged to formulate conclusions based on evidence gathered from the investigations. The teachers still gave chances for students to think logically and critically about the investigations. In all of the lessons, students were provided with opportunities to communicate their data and conclusions with other students. By doing so, students learned to evaluate and justify their conclusions against alternative ones. However, individual teachers help students see the connections between the conclusions (new knowledge) and their prior knowledge only in one lesson (per teacher).

When comparing the teachers' understandings with their practices, the findings indicated that, in general, the three teacher's practices were aligned with their understandings, particularly in terms of the teacher role and the instructional objective. For the student's role, Phichit's and Monsid's practices complied with their understandings. However, for Suriya, students played a role that differed from his understanding. With regard to instructional process, the three teachers' practices were in agreement with their understandings, except in the aspect of conclusion/explanation. In this regard, Monsid's and Suriya's teaching practices did not agree with their understandings. The two teachers recognized that students should analyze data and formulate conclusions by themselves. However, in practice, the teacher and students analyzed data and formulated conclusions together. Suriya did not have data analysis and conclusions in some lessons.

When comparing the teachers' understandings and practices with the essential features of IBI, the results indicated that, for the most part, the three teachers' understandings and practices were aligned with the essentials features of IBI, particularly in terms of the role of the teacher, the role of the students and the instructional objective. The three teachers accepted the multiple roles of the teacher. The roles they identified in common included guide, motivator, facilitator, and activity director. The teachers also recognized that the student should assume the role of active and minds-on investigator. All of the teachers focused their inquiry-based lessons on scientific knowledge, science process skills, and scientific attitudes consistent with the NSCS.

With regard to instructional process, the three teachers' understandings and practices were compliant with a number of essential features of IBI including: 1) the inquiry process begins by motivating students' interest or curiosity; 2) the teacher should elicit students' prior knowledge; 3) students should have a scientifically oriented question as a goal for doing investigations; 4) students conduct investigations and collect data; 5) students, the teacher, or both design the investigation; 6) the scientifically oriented question is answered by a scientific investigation; 7) students, the teacher, or both parties analyze data gathered from investigation; 8) students communicate and justify their conclusion/explanation with other students; 9) students evaluate their conclusion/explanation in the light of alternative ones; 10) students, the teacher, or both connect conclusions/explanations to scientific knowledge; and 11) students have a chance to learn through social interaction during group work.

Nevertheless, the findings showed that even after taking part in the professional development program, the three teachers rarely connected new knowledge with students' prior knowledge. After engaging in the professional development program, the three teachers linked new knowledge with students' prior understanding in one lesson per teacher.

Implications of the Study

This section provides the implications of the research study. The implications are presented in relation to professional development, science teaching and learning through inquiry, research methodology, and further studies.

Implications for Professional Development

The professional development program utilized in this study involved the use of basic elements of action research and collaborative action research to promote the teachers' understandings and practices of IBI in their actual classrooms. According to the results of this study, the CAR Program is productive in affecting changes of the case study teachers' understandings and their use of IBI in the classroom. The crucial components underlining the CAR Program that are likely to have an impact on the development of the science teachers might be: establishing common goals among program members, empowering teachers' leadership of the professional development program, providing opportunities for teachers to learn in their actual classrooms, giving time and support for teachers to plan, implement, observe, and reflect on their lessons, providing chances for teachers to learn through the recurrence of the action-reflection cycle, having long-term assistance for continuous learning and practical change, and most importantly building and sustaining a trusting and respectful atmosphere among the teachers and the researcher.

Implications for Teaching Science through IBI

The results of this study suggest several conditions may need to be in place for science teachers to be successful in teaching science through IBI, particularly in a classroom similar to the students in the case study teachers' classes. First, the science teacher needs to build a good relationship with students. Teachers who have a good relationship with students are more likely to have students' cooperation when experimenting with new pedagogical approaches. Second, strong subject matter knowledge may make it easier for the science teacher to teach science through IBI. In the case of this study, the three teachers agreed that in teaching science via IBI they tended to choose science concepts that they were knowledgeable about. The teachers noted if they selected a concept that they were less knowledgeable about, it was difficult for them to plan and implement the lesson. In addition, they could not assist students to achieve the intended learning outcomes. Third, the science teacher should initially use a teacher-directed level of inquiry when he/she teaches students who have had little experience with active learning and/or participation. The study suggests that teacher should provide time and support for students to experience teacher-directed inquiry until students are familiar with the approach and have skills necessary for moving to a more leaner-directed inquiry. Fourth, the science teacher should have a short activity that is effective in stimulating students' curiosity. Based on the study, discussion was not enough to capture students' interest. The motivational activities that were productive tended to be the ones that were hands-on, related to students' daily lives, and exciting. Without students' interest, it was not easy for the learning objective to be accomplished due to the fact that students were not willing to become active learners in a class that they were not interested in. Last, the science teacher should provide guiding questions for students when they are being asked to review reliable resources. The results of this study showed that students experienced difficulty when asked to review information from learning resources. Many students could not identify the important or relevant information from the learning resources. One way to aid students with this review task is to give them guiding questions as they read.

Implications for Methodology

Since generalization is not the goal of a qualitative case study, the strategy used for selection of the sample of this study is purposeful sampling. Science teachers were chosen initially based on the criterion that they taught science at the lower secondary level in the schools participated in the EOLS Project in Bangkok. The teachers were then selected by considering three other criteria: their lack of opportunity to engage in any professional development programs/workshops related to IBI during the past three years, their willingness to involve in the professional development program, and their school area. This sampling method enables the researcher to learn and gain a profound understanding of the case studies that are being investigated (Patton, 2001). One additional assumption guiding teacher selection was that science teachers from similar contexts might be able to understand issues confronted in classrooms, provide suggestions, and learn from each other better than those who came from diverse circumstances.

The data analysis of this study includes within-case and cross-case analyses. Once the data is analyzed, the findings are reported via thick description. These methods of data analysis and result presentation aim to assist readers to understand more clearly about individual teachers. This presentation method is also recognized as a powerful way to provide readers a better understanding of each individual case when compared with presenting the results using abstract theories or principles. In this regard, both results and contexts surrounding each teacher are presented. The readers are invited to reinterpret or create their own stories about the teachers' understandings and practices in relation to IBI.

At the beginning of this study, the researcher attempted to immerse herself into the field. During the first month of the study, the researcher frequently met the teachers in their schools, visited the teachers' classrooms, and talked informally with the teachers and students. These school visits were intended to build up a trusting, respectful, and familiar atmosphere between the researcher and teachers, as well as to familiarize the researcher with the teachers' contexts. Without this kind of atmosphere, the researcher believed she would not receive the teachers' cooperation in the CAR Program. Thus, based on the experiences of the researcher, it appears to be important for the researcher to immerse him/herself in the field with an effort to build up a positive atmosphere with the program's participants before he/she continues to the next step of inquiry.

Implications and Recommendations for Further Study

The results of this study indicate that participation in CAR was a successful strategy for promoting changes in science teachers' understandings and practices of IBI from a teacher-directed type to a less teacher-directed or leaner-directed type. However, the study does not investigate the process that individual teachers learn to change their understanding and practice. Thus, this study suggests that there is value in future research, particularly in a Thai context, to study how science teachers learn to change their understandings and practices in the context of a professional development model similar with this one. There is also the need for future study to investigate how science teachers sustain their new understandings and practices during or after they leave the professional development program.

For readers and researchers who are interested in doing similar studies, it is important to remember that this study was conducted with a group of three science teachers who taught at the lower secondary level in two lower secondary schools participating in the EOLS Project in Bangkok. The findings from this study were not intended to generalize to all science teachers. Nevertheless, the description of how the CAR approach to professional development was implemented and the context surrounding the use of this approach may be useful to others who decide to use this as model for teacher professional development in their own context.

REFERENCES

Altrichter, H. 1991. “Do we need an alternative methodology for doing alternative research?” In O. Zuber-Skerrit. (ed.). **Action Research for Change and Development.** England: Gower-Avebury, 79-92.

Anderson, R. D. 2002. "Reforming science teaching: What research says about inquiry." **Journal of Science Teacher Education** 13 (1): 1-12.

Anderson, R. D. 2002. "Reforming science teaching: What research says about inquiry." **Journal of Science Teacher Education** 13 (1): 1-12. cited R. D. Anderson. 1996. **Study of Curriculum Reform**. Washington, DC: Government Printing Office.

Atagi, R. 2002. **The Thailand Educational Reform Project: School Reform Policy**. Report to the Office of the National Education Commission. March 2002. Bangkok: Office of the National Education Commission.

Balach, C. A., and G. J. Szymanski. 2003. **The Growth of a Professional Learning Community through Collaborative Action Research.** Paper presented at the 2003 Annual Meeting of the American Educational Research Association, Chicago.

Barrow, L. H. 2006. "A brief history of inquiry: From Dewey to standards." **Journal of Science Teacher Education** 17 (3): 265-278.

Barrow, L. H. 2006. "A brief history of inquiry: From Dewey to standards." **Journal of Science Teacher Education** 17 (3): 265-278. cited J. Dewey. 1938. **Experience and Education**. New York: Collier Books.

Bell, C. A. 2002. **Determining the Effects of a Professional Development Program on Teachers' Inquiry Knowledge and Classroom Action: A Case Study of a**

Professional Development Strategy. Doctor of Philosophy Thesis in Science Education, Purdue University.

Bell, C. A. 2002. **Determining the Effects of a Professional Development Program on Teachers' Inquiry Knowledge and Classroom Action: A Case Study of a Professional Development Strategy.** Doctor of Philosophy Thesis in Science Education, Purdue University. cited E. Tafoya., D. W. Sunal, and P. Knecht. 1980. "Assessing inquiry potential: A tool for curriculum decision makers." **School Science and Mathematics** 80 (1): 43-48.

Blumenfeld, P. C., J. S. Krajcik, R. W. Marx, and E. Soloway. 1994. "Lessons learned: How collaboration helped middle grade science teachers learn project-based." **Elementary School Journal** 94 (5): 537-551.

Bongkotphet, T. 2009. **The Evolution of Elementary Teachers' Knowledge/Beliefs of Inquiry Teaching in Astronomy through Case-Based Pedagogy.** Doctor of Philosophy Thesis in Science Education, Kasetsart University.

Briscoe, C., and J. Peters. 1997. "Teacher collaboration across and within schools: Supporting individual change in elementary science teaching." **Science Education** 81: 51-65.

Bybee, R. W. 2000. "Teaching science as inquiry." In J. Minstrell, and E. H. van Zee. (eds.). **Inquiring into Inquiry Learning and Teaching in Science.** Washington, DC: American Association for the Advancement of Science, 20-46.

Bybee, R. W., J. A. Taylor, A. Gardner, P. V. Scotter, J. C. Powell, A. Westbrook, and N. Landes. 2006. **The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications**. Colorado: The Biological Science Curriculum Study (BSCS).

Carr, W., and S. Kemmis. 1986. **Becoming Critical: Education, Knowledge and Action Research**. Geelong: Deakin University Press.

Capobianco, B. M. 2002. **Making Science Accessible through Collaborative Science Teacher Action Research on Feminist Pedagogy.** Doctor of Education Thesis, University of Massachusetts Amherst.

Chang, C., and S. Mao. 1999. "Comparison of Taiwan science students' outcomes with inquiry-group versus traditional instruction." **Journal of Educational Research** 92 (6): 340-346.

Chiappetta, E. L., and T. R. Koballa. 2006. **Science Instruction in the Middle and Secondary Schools.** 6th ed. New Jersey: Pearson Education.

Christensen, A. J. 2005. **Science Teachers' Exploration of Practice through Collaborative Action Research.** Doctor of Education Thesis in Teachers College, Columbia University.

Cochran-Smith, M., and S. L. Lytle. 1992. **Inside/Outside: Teacher Researcher and Knowledge**. New York: Columbia University.

Colburn, A. 2000. "An inquiry primer." **Science Scope** 23 (6): 42-44.

Collins, S. 2004. "Ecology and ethics in participatory collaborative action research: An argument for the authentic participation of students in eduational research." **Educational Action Research** 12 (3): 347-362.

Corey, S. M. 1953. **Action Research to Improve School Practices**. New York: Columbia University.

Costenson, K., and A. E. Lawson. 1986. "Why isn't inquiry used in more classrooms?" **The American Biology Teacher** 48 (3): 150-158.

Curriculum Planning & Development Division. 2004. **Science Syllabus: Lower Secondary**. Singapore: Ministry of Education.

Darling-Hammond, L. 1996. "The quiet revolution rethinking teacher development." **Educational Leadership** 53 (6): 4-10.

Denzin, N. K. 1989. **Interpretive Interactionism**. California: Sage Publications.

Department of Curriculum and Instruction Development (DCID). 2002. **National Science Curriculum Standards**. Bangkok: Express Transportation Organization of Thailand. (in Thai).

Department of Curriculum and Instruction Development (DCID) and Institute for the Promotion of Teaching Science and Technology (IPST). 2002. **The Manual of Science Teaching and Learning**. Bangkok: Express Transportation Organization of Thailand. (in Thai).

Dewey, J. 1910. "Science as subject-matter and as method." **Science** 31 (787): 121-127.

Dey, I. 1993. **Qualitative Data Analysis: A User-Friendly Guide for Social Scientists**. London: Routledge.

De Zeeuw, G. 2003. "Helping others: Project or research?" **Journal of Community & Applied Social Psychology** 13 (6): 496-503.

Elliott, J. 1991. **Action Research for Educational Change.** England: Open University Press.

Exploratorium Institute for Inquiry. 1998. **A Description of Inquiry** (Online). http://www.exploratorium.edu/IFI/about/inquiry.html, October 6, 2008.

Flick, L. B. 1995. **Complex Classrooms: A Synthesis of Research on Inquiry Teaching Methods and Explicit Teaching Strategies.** Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Francisco.

Fontana, A., and J. H. Frey. 2000. "The interview from structured question to negotiated text. In N. K. Denzin, and Y. S. Lincoln. (eds.). **Handbook of Qualitative Research.** 2nd ed. California: Sage Publications, 645-672.

Gallagher, J. J., and G. K. Tobin, (eds.). 1991. **Interpretive Research in Science Education**. Manhattan: National Association for Research in Science Teaching (NARST).

Haury, D. L. 1993. **Teaching Science through Inquiry** (Online). http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED359048 &site=ehost-live, July 9, 2006.

Hinrichsen, J., and D. Jarrett. 1999. **Science Inquiry for the Classroom: A Literature Review.** Report to the Northwest Regional Educational Laboratory. December 1999. Portland: Northwest Regional Educational Laboratory.

Institutes for the Promotion of Teaching Science and Technology (IPST). 2002. **National Science Curriculum Standards**. Bangkok: Karusapa Press.

Jeanpierre, B., K. Oberhauser, and C. Freeman. 2005. "Characteristics of professional development that effect change in secondary science teachers' classroom practices." **Journal of Research in Science Teaching** 42 (6): 668-690.

Johnson, D. W., and R. T. Johnson. 1991. **Learning Together and Alone: Cooperative, Competitive, and Individualistic Learning.** 3rd ed. Englewood Cliffs, N.J.: Prentice-Hall.

Juntaraprasert, A. 2009. **Using Lesson Study to Understand How Elementary Science Teachers Translate Social Constructivist Learning Theory into Practice.** Doctor of Philosophy Thesis in Science Education, Kasetsart University.

Kemmis, S., and R. McTaggart. 1988. **The Action Research Planner.** 3rd ed. Geelong: Deakin University Press.

______. 2000. "Participatory action research." In N. K. Denzin, and E. G. Guba. (eds.). **Handbook of Qualitative Research.** 2nd ed. California: Sage Publications, 567-605.

Ketsing, J., and V. Roadrangka. 2008. "A study of teaching ecology in lower secondary schools under the project for extension of educational opportunity in Bangkok." **KKU Research Journal** 13 (11): 1332-1344. (in Thai).

Keys, C. W., and L. A. Bryan. 2001. "Co-constructing inquiry-based science with teachers: Essential research for lasting reform." **Journal of Research in Science Teaching** 38 (6): 631-645.

Krajcik, J. S., P. C. Blumenfeld, R. W. Marx, and E. Soloway. 1994. "A collaborative model for helping middle grade science teachers learn project-based instruction." **Elementary School Journal** 94 (5): 483-497.

Kvale, S. 1996. **Interviews: An Introduction to Qualitaive Research Interviewing**. California: Sage Publications.

Lewin, K. 1946. "Action research and minority problems." **Journal of Social Issues** 2 (4): 34-46.

Liewellyn, D. 2005. **Teaching High School Science through Inquiry**. California: A joint publication Corwin Press and NSTA Press.

Lincoln, Y. S., and E. G. Guba. 1985. **Naturalistic Inquiry**. California: Sage Publications.

Makang, D. S. 2003. **Analysis of an Inquiry-Oriented Inservice Program in Affecting Science Teaching Practices.** Doctor of Education Thesis, Boston University.

Marshall, C. and G. B. Rossman. 2006. **Designing Qualitative Research.** 4th ed. California: Sage Publications.

Marx, R. W., P. C. Blumenfeld, J. S. Krajcik, M. Blunk, B. Crawford, B. Kelly, and K. M. Meyer. 1994. "Enacting project-based science: Experiences of four middle grade teachers." **Elementary School Journal** 94 (5): 517-538.

McKerman, J. 1991. **Curriculum Action Research: A Handbook of Methods and Resources for the Reflective Practitioner**. London: Kogan Page Limited.

McMillan, J. H., and S. Schumacher. 1997. **Research in Education.** 4th ed. New York: Addison-Wesley Educational Publishers Inc.

McNiff, J., P. Lomax, and J. Whitehead. 1996. **You and Your Action Research Project.** London: Routledge Falmer.

McNiff, J., and J. Whitehead. 2002. **Action Research: Principles and Practice.** 2nd ed. London: Routledge Falmer.

Merriam, S. B. 1998. **Qualitative Research and Case Study Applications in Education.** 2nd ed. San Francisco: Jossey-Bass Publishers.

Meinoratha, J. 1997. **Science Instruction Organization in Schools under the Project for Extension of Educational Opportunity at the Lower**

Secondary Level of the Bangkok Metropolis Administration. Master of Arts in Teaching Thesis in Teaching Science, Kasetsart University. (in Thai).

Minstrell, J. 2000. "Implications for teaching and learning inquiry: A Summary." In J. Minstrell, and E. H. van Zee. (eds.). **Inquiring into Inquiry Learning and Teaching in Science.** Washington, DC: American Association for the Advancement of Science, 471-496.

Minstrell, J., and E. H. van Zee, (eds.). 2000. **Inquiring into Inquiry Learning and Teaching in Science**. Washington, DC: American Association for the Advancement of Science.

National Research Council. 1996. **National Science Education Standards**. Washington, DC: National Academy Press.

______. 2000. **Inquiry and the National Science Education Standards: A Guide for Teaching and Learning**. Washington, DC: National Academy Press.

Naylor, C. S. 2007. **Collaborative Teacher Inquiry as Professional Development: Concepts, Contexts and Directions.** Doctor of Philosophy Thesis in Language Education, University of British Columbia.

Noffke, S. E. 1995. "Action research and democratic schooling: problematics and potentials." In S. E. Noffke, and R. B. Stevenson. (eds.). **Educational Action Research.** New York: Teachers College Press.

Novak, A. 1964. "Scientific inquiry." **BioScience** 14 (10): 25-28.

Office of the Education Council. 2001. **A Report on the Research and Development for the Policy Involving of a Reformation of Science Education in Thailand.** Bangkok: Office of the Education Council, Ministry of Education.

______. 2004. **Guideline for School-Based Training (SBT) for In-service Teacher Development.** Bangkok: Office of the Education Council, Ministry of Education.

Office of the National Education Commission (ONEC). 2003. **National Education Act B.E. 2542 (1999) and Amendments.** Bangkok: Pimdeekarnpim Co., Ltd.

Oja, S. N. and L. Smulyan. 1989. **Collaborative Action Reserach: A Developmental Approach**. New York: Falmer Press.

Patton, M. Q. 2002. **Qualitative Research & Evaluation Methods.** 3rd ed. California: Sage Publications.

Pillay, H. 2002. **Teacher Development for Quality Learning: The Thai Education Reform Project**. Report to the Office of the National Education Commission. March, 2002. Bangkok: Office of the National Education Commission, Ministry of Education.

Puntumasen, P. 2004. **School-Based Training (SBT) for In-service Teacher Development: A Strategy for the Success of Learning Reform in Thailand.** Paper presented at the Learner-centered Approach from the Perspectives of Forum Participant, Hong Kong.

Roadrangka, V., and P. Dachakop. 1989. **Science Process Skills: Teacher Manual** Bangkok: Institute of Academic Development. (in Thai).

Roadrangka, V., N. Yutakom, and P. Chaiso. 2008. "The state of teaching and learning science according to basic science curriculum reform in Thailand." **KKU Research Journal** 13 (11): 1217-1235.

Roehrig, G. H., and J. A. Luft. 2004. "Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons." **International Journal of Science Education** 26 (1): 3-24.

Rossman, G. B., and S. F. Rallis. 2003. **Learning in the Field: An Introduction to Qualitative Research.** 2nd ed. California: Sage Publications.

Rutherford, F. J. 1968. "The role of inquiry in science teaching." In W. D. Romey. (ed.). **Inquiry Techniques for Teaching Science.** New Jersey: Prentice-Hall, Inc., 264-270.

Sangpradit, T. 2009. **Enhancing Lower Secondary School Thai Students' Understanding of Light: Social Constructivist Approach.** Doctor of Philosophy Thesis in Science Education, Kasetsart University.

Schwab, J. J. 1960. "Enquiry, the science teacher, and the educator." **The Science Teacher** 27: 6-11.

Shymansky, J. 1984. "BSCS programs: Just how effective were they?" **The American Biology Teacher** 46 (1): 54-57.

Singdumrong, N. 2000. **Needs for Personnel Development of Teachers in the Expanding Access to Lower Secondary Education Schools under the Bangkok Metropolitan Administration.** Master of Education Thesis in Educational Administration, Kasetsart University. (in Thai).

______. 2000. **Needs for Personnel Development of Teachers in the Expanding Access to Lower Secondary Education Schools under the Bangkok Metropolitan Administration.** Master of Education Thesis in Educational Administration, Kasetsart University. (in Thai). cited Department of Education Bangkok Metropolitan Administration (BMA). 1999. **Summary of Seminar: Problems, Obstracles, Solutions for Teahing and Learning in**

Schools Participating in the EOLS Project in Bangkok. Bangkok: Department of Education Bangkok Metropolitan Administration. (in Thai).

Sivan, E. 1986. "Motivation in social constructivist theory." **Educational Psychologist** 21 (3): 209-233.

Soparat, S. 2008. **Developing and Using a Professional Development Model for Enhancing Thai Elementary Science Teacher Teaching: A Reflective, Inquiry-Based Approach.** Doctor of Philosophy Thesis in Science Education, Kasetsart University.

Stake, R. E. 2000. “Case studies.” In N. K. Denzin, and Y. S. Lincoln. (eds.). **Handbook of Qualitative Research.** 2nd ed. California: Sage Publications, 435-454.

Stringer, E. 2007. **Action Research.** 3rd ed. Los Angeles: Sage Publications.

Tippins, D. J. 2006. **Insights into Qualitative Research Science Education: A Workshop in Parthership with the University of Georgia and Kasetsart University.** Department of Education, Faculty of Education, Kasetsart University. (Mimeographed).

Unesco. 1986. **School-based In-service Training: A Handbook**. Bangkok: Unesco Regional Office for Education in Asia and the Pacific.

van Driel, J. H., D. Beijaard, and N. Verloop. 2001. "Professional development and reform in science education: The role of teachers' practical knowledge." **Journal of Research in Science Teaching** 38 (2): 137-158.

van Zee, E., D. Lay, and D. Roberts. 2003. "Fostering collaborative inquiries by prospective and practicing elementary and middle school teachers." **Science Education** 87 (4): 588-612.

Wee, B., D. Shepardson, J. Fast, and J. Harbor. 2007. "Teaching and learning about inquiry: Insights and challenges in professional development." **Journal of Science Teacher Education** 18 (1): 63-89.

Welch, W. W., L. F. Klopfer, G. S. Aikenhead, and J. T. Robinson. 1981. "The role of inquiry in science education: Analysis and recommendations." **Science Education** 65 (1): 33-50.

Winter, R. 1996. "Some principles and procedures for the conduct of action reserach." In O. Zuber-Skerritt. (ed.). **New Directions in Action Research.** London: Falmer Press.

Woolnough, B. E. 2000. "Appropriate practical work for school science: Making it practical and making it science." In J. Minstrell, and E. H. van Zee. (eds.). **Inquiring into Inquiry Learning and Teaching in Science.** Washington, DC: American Association for the Advancement of Science, 434-446.

Yutakom, N. and P. Chaiso. 2007. **Inservice Science Teacher Professional Development in Accordance with the National Education Act of B.E. 2542 (1999)**. Report to the Institute for the Promotion of Teaching Science and Technology. September, 2007. Bangkok: Kasetsart University. (in Thai.).

Zion, M., M. Slezak, D. Shapira, E. Link, N. Bashan, M. Brumer, T. Orian, R. Nussinowitz, D. Court, B. Agrest, R. Mendelovici, and N. Valanides. 2004. "Dynamic, Open Inquiry in Biology Learning." **Science Education** 88 (5): 728-753.

Zuber-Skerritt, O. 1991. **Action Research for Change and Development.** Aldershot, Hampshire: Gower-Avebury.

APPENDICES

Appendix A

Reflective Protocol

Reflective Protocol for Phase 1

Written Reflection of Inquiry-Based Instruction
General Science Subject
Lower Secondary Level
For Schools Participating in the EOLS Project

Explanation

Please write or type a reflection on your classroom teaching of this lesson and then give this reflection to the researcher. In the reflection, please describe your actions (things you actually did in class), thoughts (things you think you should/shouldn't do), and feeling according to the following questions:

1. General Information
    - Grade Level
    - Topic of Study
    - Number of Students (Male/Female)
    - Learning Objectives
2. What do you think or feel with your teaching in this lesson? Please provide evidences that support you thinking and feeling.
3. Do you think whether or not the students achieve learning objectives in this lesson? Why do you believe that? Please explain.
4. What are the things you did in this lesson that you think/feel appropriate for students in terms of their science learning? Why?
5. If you have a chance to teach this topic again, what will you do that are different from this lesson? How these differences help students in terms of their science learning?
6. What are the actions you did in this lesson that you want to keep for your future teachings? Why?
7. What are the actions you did in this lesson that you *do not* want to keep for your future teachings? Why?

8. What have you learned from this lesson in relation to inquiry-based instruction?
9. What are the problems or issues occurred in this lesson that you want to solve/ improve?

Yours sincerely,

………………………….

(Ms. Jeerawan Ketsing)

Ph.D. Candidate

The Program to Prepare Research and Development Personnel for Science Education

Department of Education, Faculty of Education, Kasetsart University

Reflective Protocol for Phase 2-4

Written Reflection of Inquiry-Based Instruction

General Science Subject

Lower Secondary Level

For Schools Participating in the EOLS Project

Explanation

Please write or type a reflection on your classroom teaching of this lesson and then give this reflection to the researcher. In the reflection, please describe your actions (things you actually did in class), thoughts (things you think you should/shouldn't do), and feeling according to the following questions:

1. General Information
   - Grade Level
   - Topic of Study
   - Number of Students (Male/Female)
   - Learning Objectives
2. Do you think whether or not the students achieve learning objectives in this lesson? Why do you believe that? Please explain.
3. Did you elicit students' prior knowledge in this lesson? If yes, how did you do?
4. What is/are the main questions students address in this lesson? Do you think this question is scientifically oriented question? Why?
5. Do you think students were interested in that main question? What did you do to motivate students' interest of the main question?
6. How did students address the main question? What was a scientific investigation that students use for answering the question?
7. Who was the one design the investigation? (students, the teacher, or both) please explain.
8. Who was the one to analyze data gathered from the investigation and to formulate conclusion/explanation? How did you do?

9. Did you connect the conclusion/explanation with students' prior knowledge? If yes, how did you do?
10. Did you link the conclusion/explanation related science concepts? If yes, how did you do?
11. Did you have students learn in groups in this lesson? If yes, how did you group students? Why?
12. What do you think as your role in this lesson? Why do you believe that, please explain?
13. What do you think as student role in this lesson? Why do you believe that, please explain?
14. What are the things you did in this lesson that you think/feel appropriate for students in terms of their science learning? Why?
15. What are the things you did in this lesson that you think/feel *inappropriate* for students in terms of their science learning? Why?
16. What have you learned from this lesson in relation to inquiry-based instruction?
17. What are the problems or issues occurred in this lesson that you want to solve/ improve?

Yours sincerely,

………………………….

(Ms. Jeerawan Ketsing)

Ph.D. Candidate

The Program to Prepare Research and Development Personnel for Science Education

Department of Education, Faculty of Education, Kasetsart University

Appendix B

Semi-structured Interview Protocol

Semi-structured Interview Protocol of Teacher's Understanding of Inquiry-Based Instruction before Participation in the CAR Program

(for Phase 1)

Teacher: ________________________________

School: ________________________________

Interviewer: _____________________________

Date: _______________Time:________________

Interview Context:

____

____

Part 1: Teacher's Background

1. Education
2. Science teaching experience (in general and in lower secondary level)
3. Number of students in a classroom

Part 2: Teacher's Understanding of IBI

1. How do you teach general science subject, in particular?
2. What is inquiry-based instruction according to your understanding?
    - What is/are the teacher role in inquiry-based classroom?
    - What is/are the student role in inquiry-based classroom?
3. Have you ever taught general science through inquiry?
    - If yes, what are the reasons you decide to teach your lesson through inquiry?
        - What kind of lesson/content that you believe suitable for inquiry teaching?
        - Could you give an example of inquiry-based lesson that you used or have experienced? (Continue with item 4)
    - If no, what are the reasons that you do not use this approach in your lessons?

- Could you think of any teachers or classes that taught via inquiry? What did the teacher or students did in that lesson? (Continue with item 4)

4. What the teacher did/should do for introduce the inquiry-based lesson?
5. What do students do to study the lesson?
6. Who was the one to design investigation students used in the lesson?
7. Which was the method students used for collecting data? How do students get the method?
8. How did students do to make conclusion?
9. Did students have a chance to share their conclusion with other? If yes, how did they present their conclusion?
10. Did students have a chance to work in group? If yes, how did they work in groups? What do you think about group work?
11. What do you view as benefits and limitations of inquiry-based instruction?
12. What do you want to change or improve in terms of your teaching through inquiry?
13. What is your expectation or hope to gain by engaging in this professional development program?
14. Do you have any questions or suggestions regarding this interview?

Semi-structured Interview Protocol of Teacher's Understanding of Inquiry-Based Instruction during Participation in the CAR Program

(for Phase 2-4)

Teacher: ________________________________

School: _________________________________

Interviewer: ______________________________

Date: ______________Time:_______________

Interview Context:

____

____

1. What are the learning objectives of this lesson?
2. Do you think students achieve the learning objectives?
    - If yes, which are the objectives they achieve? How do you know?
    - If no, which are the objectives they don't achieve? How do you know?
3. Did you elicit students' prior knowledge in this lesson?
    - If yes, what did you do?
    - If no, why didn't you do?
4. What is the main question (scientifically oriented question) that students address in this lesson? How do they get the question?
5. Do you think students are interested in this question?
    - If yes, how do you know? What did you do to motivate their interest?
    - If no, why don't you do?
6. What is the way/method students used for answering the question? How do students get that way/method?
7. How did students record and analyze the data? How do they get the way/technique for recording and analyzing data?
8. How did students make conclusion or formulate answer of the main question?
9. Did students have a chance to communicate their conclusion with the others?
    - If yes, how did they do?

- If no, why don’t you do

10. Did students have a chance to connect the conclusion with their prior knowledge?
    - If yes, how did they do?
    - If no, why don’t you do
11. Did you introduce the related science concepts to students, after completing investigation?
    - If yes, how did you do?
    - If no, why don’t you do?
12. How do you have students work in groups in this lesson?
13. What do you believe as your role in this lesson?
14. What do you think as the student role in the lesson?
15. What are the things that you want to change or improve in relation to your teaching of inquiry-based instruction?
16. At present, do you think you have a better understanding of inquiry? Why? What do you know more, in short?
17. Do you have any questions or suggestions regarding this interview?

Appendix C

Schedule of Overall Meetings with Teachers

Appendix Table C1 Schedule of Overall Meetings with Teachers

M/D/Y	Participant	Activity	Time
Phase 1: Preparation			
Jul. 08, 2008	Manthana[6]	- Visit school/classroom - Explain the study plan - Set up shared goals	08.30-11.00
Jul. 09, 2008	Suriya	- Visit school/classroom - Explain the study plan - Set up shared goals	13.00-15.00
	Phichit	- Visit school/classroom - Explain the study plan - Set up shared goals	08.30-11.00
Jul. 16, 2008	Suriya	- Visit school/classroom - Practice reflective writing	13.00-15.00
Jul. 23, 2008	Suriya	- Visit school/classroom - Practice reflective writing - Advise the teacher regarding the reflective writing	13.00-15.00
Jul. 24, 2008	Phichit	- Visit school/classroom - Practice reflective writing	08.30-10.30
	Manthana	- Visit school/classroom - Practice reflective writing	12.00-15.00
Jul. 28, 2008	Phichit Monsid	- Visit school - Explain the study plan - Set up shared goals	12.30-14.30
Jul. 31, 2008	Phichit	- Visit school/classroom - Advise the teacher regarding the reflection - Practice reflective writing	08.30-10.30

[6] Manthana had to resign from this study earlier because she was assigned by her school administrator to engage in another project.

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
Phase 1: Preparation (Continued)			
Jul. 31, 2008	Manthana	- Visit school/classroom - Advise the teacher regarding the reflection - Practice reflective writing	12.00-15.00
Aug. 05, 2008	Monsid	- Visit school/classroom - Practice reflective writing	08.30-11.00
Aug. 08, 2008	Monsid	- Visit school/classroom - Advise the teacher regarding the reflective writing - Practice reflective writing	08.30-10.00
Aug. 14, 2008	Phichit	- Classroom observation - Interview #1	08.30-09.30 40 minutes
Aug. 15, 2008	Monsid	- Classroom observation - Interview #1	08.30-10.30 60 minutes
Aug. 20, 2008	Phichit	- Classroom observation - Written reflection #1	08.30-10.30
	Suriya	Classroom observation Written reflection #1	13.30-14.30
Aug. 22, 2008	Suriya	Interview #1	45 minutes
Aug. 26, 2008	Monsid	- Classroom observation - Written reflection #1	08.30-10.30
Aug. 29, 2008	Monsid	Classroom observation	08.30-10.30
Sep. 05, 2008	Monsid	- Classroom observation - Written reflection #2	08.30-09.30
Sep. 09, 2008	Monsid	- Classroom observation - Written reflection #3	08.30-10.30
Sep. 10, 2008	Phichit	- Classroom observation - Written reflection #2	08.30-10.30

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
Phase 1: Preparation (Continued)			
Sep. 11, 2008	Phichit	- Classroom observation - Written reflection #3	08.30-10.30
Sep. 15, 2008	Suriya	- Classroom observation - Written reflection #2	09.30-10.30
Sep. 17, 2008	Suriya	Classroom observation	13.30-14.30
Sep. 18, 2008	Suriya	- Classroom observation - Written reflection #3	10.30-11.30
Oct. 13, 2008 (School break)	CAR Team	1st Central Meeting	08.30-14.30
Phase 2: CAR Cycle I			
Nov. 01-16, 2008	Individual teachers	Design an inquiry-based lesson plan	17 days
Nov. 17, 2008	Suriya	Classroom observation	10.30-11.30
	Monsid	Classroom observation	12.30-13.30
Nov. 18, 2008	Monsid (Phichit joined some parts of the conversation)	- Classroom observation (Continued) Interview #2 - Assist the teacher regarding lesson plan and instruction. Topics for consulting include concept begin focused, learning objective (scientific knowledge, science process skills, scientific attitudes), group work, formulation of conclusion, motivational activity, scientifically oriented question, scientific investigation, content knowledge, assessment and evaluation, communication of data, respect of other people’ opinions, value students’ answers, difficulty in teaching. - Written a reflection #4	08.30-10.30 40 minutes 2.30 hours

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
Phase 2: CAR Cycle I (Continued)			
Nov. 20, 2008	Suriya	Classroom observation (Continued)	10.30-11.30
Nov. 21, 2008	Suriya	- Classroom observation (Continued) - Interview #2 - Assist the teacher regarding lesson plan and instruction. Topics for consulting include concept being focused, expected learning outcome from the NSCS, learning objective (scientific knowledge, science process skills, scientific attitudes), assessment and evaluation, a consistency between learning objective and instructional process, motivational activity, deductive and inductive instruction, concept map, encouraging students to answer questions (no force), questioning and sequence of questions asked, and designing the lesson by considering the essential features of IBI. - Written reflection #4	10.30-11.30 30 minutes 2.45 hours
Dec. 01, 2008	Phichit	Classroom observation	09.30-11.30
Dec. 02, 2008	Phichit	Classroom observation (Continued)	09.30-11.30
Dec. 03, 2008	Phichit	- Interview #2 - Assist the teacher regarding lesson plan and instruction. Topics of consulting include learning objective (scientific knowledge, science process skills, scientific attitudes), prior knowledge, motivational activity, group work, scientifically oriented question,	40 minutes 1.30 hour

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
Phase 2: CAR Cycle I (Continued)			
		experiment, data collection, science process skills, formulation of conclusion, time allocation, safety, discussion before experiment, deductive and inductive instruction, level of inquiry, relating learning activity to students' daily lives, communication of finding and conclusion, and concept being investigated. - Written reflection #4	
Dec. 10, 2008 (Holiday)	CAR Team	2nd Central Meeting	09.00-13.30
Phase 3: CAR Cycle II			
Dec. 12, 2008 – Jan 04, 2009	Individual teachers	Design an inquiry-based lesson plan	24 days
Jan. 05, 2009	Suriya	Classroom observation	09.30-10.30
Jan. 06, 2009	Monsid	Classroom observation	08.30-10.30
Jan. 07, 2009	Suriya	Classroom observation (Continued)	13.30-14.30
Jan. 08, 2009	Phichit	Classroom observation	08.30-11.30
Jan. 13, 2009	Monsid	Classroom observation (Continued)	08.30-10.30
Jan. 15, 2009	Suriya	Classroom observation (Continued)	12.30-13.30
Jan. 19, 2009	Suriya	- Classroom observation (Continued) - Interview #3 - Assist with the teacher regarding lesson plan and instruction. Topics for consulting include learning objective (scientific knowledge, science process skills scientific attitudes), concept being focused, scientifically oriented question, data collection, formulation of conclusion based on evidence, communication and	09.30-10.30 40 minutes 30 minutes

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
Phase 3: CAR Cycle II (Continued)			
		justification of findings, group work, difficulties (question). - Write a reflection #5	
Jan. 20, 2009	Monsid	- Classroom observation (Continued) - Interview #3 - Assist with the teacher regarding lesson plan and instruction. Topics for consulting include expected learning outcomes from the NSCS, learning objective (scientific knowledge, scientific attitudes, and science process skills), scientifically oriented question, and assessment and evaluation. - Write a reflection #5	08.30-10.30 60 minutes 35 minutes
	Phichit	- Classroom observation (Continued) - Interview #3 - Assist with the teacher regarding lesson plan and instruction. Topics for consulting include learning objective (scientific knowledge, scientific attitudes, science process skills), concept being focused, motivational activity, scientifically oriented question, hands-on mind-on activities, formulation of conclusion based on evidence, prediction/hypothesis, discussion of data, communication of data and conclusion, assessment and evaluation, and having students to share ideas in investigation. Write a reflection #5	12.30-13.30 40 minutes 40 minutes
Jan. 24, 2009	CAR Team	3rd Central Meeting (Saturday)	09.00-13.30

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
Phase 4: CAR Cycle III			
Jan. 25 – Feb 09, 2009	Individual teachers	Design an inquiry-based lesson plan	16 days
Feb. 10, 2009	Monsid	Classroom observation	08.30-10.30
Feb. 17, 2009	Monsid	- Classroom observation (Continued) Interview #4 - Assist with the teacher regarding lesson plan and instruction. Topics for consulting include concept being focused, learning objective (scientific knowledge, science process skills, and scientific attitudes), assessment and evaluation, prior knowledge, and connection of new knowledge with prior knowledge. - Write a reflection #6	08.30-10.30 60 minutes 15 minutes
	Phichit	Classroom observation	12.30-13.30
Feb. 19, 2009	Phichit	- Classroom observation (Continued) - Interview #4 - Assist with the teacher regarding lesson plan and instruction. Topics for consulting include scientifically oriented question, communication and evaluation of data, group work, and connection of new knowledge with prior knowledge. - Write a reflection #6	08.30-10.30 40 minutes 15 minutes
Feb. 23, 2009	Suriya	Classroom observation	09.30-10.30
Feb. 25, 2009	Suriya	- Classroom observation (Continued) Interview #4 - Assist with the teacher regarding lesson plan and instruction. Topics for consulting include learning objective	13.30-14.30 40 minutes 20 minutes

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
Phase 4: CAR Cycle III			
		(scientific knowledge, science process skills, and scientific attitudes), prior knowledge, scientifically oriented question, review information from reliable resources as a method for inquiring knowledge, students' interest of question, and difficulty of instruction. - Write a reflection #6	
Feb. 28, 2009 (Saturday)	CAR Team	4th Central Meeting	09.30-13.30

Appendix D

Distribution of Activities and Data Collections of the Study

Appendix Table D1 Distribution of Activities and Data Collections of the Study

	Purposes of Activities	Activities	Data Collections	2008						2009	
				Jul.	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**
Preparation	To set up a common goal for engaging in the CAR Program.	School visits Informal talks	---								
	To build up a confidential and familiarity relationship among the researcher, teachers, and students.	School/classroom visits Informal talks	---								
	To practice teachers in written reflection.	Writing reflections	---								
	To promote accuracy of teachers' and students' actions in the classroom.	Pilot video-recording of the classroom activity.	---								
	To explore teachers' initial understanding of IBI.	Individual interview	Interview transcription								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data Collections	2008						2009	
				Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Preparation (Continued)	To explore teachers’ initial understanding and existing practice of IBI	Designing inquiry-based lesson plan, Being observation, Reflecting on practice	Inquiry-based lesson plans, Videos of classroom instruction, Written reflection								
	To encourage the teachers’ awareness of the importance of IBI in science; to set up the essential features of IBI of this study; to provide the teachers with the chance to share their lesson plan, teaching experience, and difficulties in understanding and implementing inquiry-based lesson; to assist and support each other in improving inquiry-based lessons.	First central meeting	Videos of the meeting								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data Collections	2008						2009	
				Jul.	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**
Preparation (Continued)	To learn IBI through reflection on their own instructions, communication with each other, and participation in activities designed by the researcher.	First central meeting	Videos of the meeting								
CAR Cycle I	To promote teacher's understanding and practice of IBI through the 1st action-reflection cycle.	Teacher planed an inquiry-based lesson plan	---								
		Teacher implemented the lesson in his classroom.	---								
		Researcher assisted the teacher regarding lesson plan and instruction.	---								
		Teacher observed his instruction via video.	---								
		Teacher wrote a reflection on his teaching practice.	---								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data Collections	2008 Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	2009 Jan.	Feb.
CAR Cycle I (Continued)	To explore teacher's understanding of IBI.	Individual interview	Interview transcription								
	To explore teacher's understanding and practice of IBI.	Designing inquiry-based lesson plan, Being observation, Reflecting on practice	Inquiry-based lesson plan , Videos of classroom instruction, Written reflection								
	To provide the teachers with the opportunity to share their lesson plans, teaching experiences, and difficulties in understanding and implementing inquiry-based lesson; to assist and support each other in improving inquiry-based lessons.	Second central meeting	Videos of the meeting								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data Collections	2008 Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	2009 Jan.	Feb.
CAR Cycle I (Continued)	To learn IBI through reflection on their own instructions and communi-cation with each other, and participation in activities provided by the researcher.	Second central meeting	Videos of the meeting								
CAR Cycle II	To promote teacher's understanding and practice of IBI by working through the 2nd action-reflection cycle.	Teacher planed an inquiry-based lesson plan	---								
		Teacher implemented the lesson in his classroom.	---								
		Researcher assisted the teacher regarding lesson plan and instruction.	---								
		Teacher observed his instruction via video.	---								
		Teacher wrote a reflection on his teaching practice.	---								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data collections	2008						2009	
				Jul.	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**
CAR Cycle II (Continued)	To explore teacher's understanding of IBI.	Individual interview	Interview transcription								
	To explore teacher's understanding and practice of IBI.	Designing inquiry-based lesson plan, Being observation, Reflecting on practice	Inquiry-based lesson plan, Videos of classroom instruction, Written reflection								
	To provide the teachers with the opportunity to share their lesson plans, teaching experiences, and difficulties in understanding and implement-ting inquiry-based lesson; to assist and support each other in improving inquiry-based lessons; to learn IBI through sharing and communicating with each other.	Third central meeting	Videos of the meeting								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data collections	2008 Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	2009 Jan.	Feb.
CAR Cycle III	To promote teacher's knowledge and practice of IBI by working through the 3rd action-reflection cycle.	Teacher planed an inquiry-based lesson plan	---								
		Teacher implemented the lesson in his classroom.	---								
		Researcher assisted the teacher regarding lesson plan and instruction.	---								
		Teacher observed his instruction via videotape.	---								
		Teacher wrote a reflection on their practice.	---								
	To explore teacher's understanding of IBI.	Individual interview	Interview transcription								
	To explore teacher's understanding and practice of IBI.	Plan an inquiry-based lesson plan, Classroom observation, Write a reflection on teaching practice	Inquiry-based lesson plan, Video of classroom observation, Written reflection								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data collections	2008						2009	
				Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
CAR Cycle III (Continued)	To provide the teachers with the opportunity to share lesson plan, teaching experience, and difficulties in understanding and practice of inquiry-based lesson; to assist and support each other in improving inquiry-based lesson; to learn IBI through sharing and communicating with each other.	Forth central meeting	Videos of the meeting								

BIOGRAPHICAL DATA

NAME – SURNAME	Miss Jeerawan Ketsing
DATE OF BIRTH	July 9th, 1982
PLACE OF BIRTH	Lop Buri, Thailand
EDUCATION	2008 University of British Columbia International Research Internship 2005 Kasetsart University Grad.Dip. (Teaching Science Profession) 2004 Kasetsart University B.S. (Biology)
CONFERENCES	2009 The ASERA 2009: 40th Australasian Science Education Research Association Conference, Deakin University, Geelong, Australia 2008 The 34th Congress on Science and Technology of Thailand [STT 34], Queen Sirikit National Convention Center, Bangkok, Thailand 2008 The Investigating Our Practices [IOP's]: 11th Annual Conference, University of British Columbia, Vancouver, Canada
SCHOLARSHIPS	2004 – 2010 The scholarships for pursuing B.S. (Biology), Grad.Dip. (Teaching Science Profession), and Ph.D. (Science Education) from the Project for the Production of Science and Mathematics Talented Teachers [PSMT] which is conducted jointly by the Royal Thai Government Agencies and the Institute for the Promotion of Teaching Science and Technology [IPST], Thailand 2009 The scholarships for research funding from the Graduate School, Kasetsart University, Thailand