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THESIS

ENHANCING PHYSICS TEACHERS' TEACHING PRACTICES THROUGH COLLABORATIVE ACTION RESEARCH IN RESPONSE TO THAILAND'S EDUCATION REFORM

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A Thesis Submitted in Partial Fulfillment of

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This naturalistic research examines the possibility and potential of using collaborative action research (CAR) as an alternative approach to science teacher development in the context of Thailand. It involves a group of physics teachers and a researcher working and learning together to initiate actions in order to improve teaching practice in response to Thailand's education reform movement. The research consists of two consecutive phases. In the first phase, the researcher aims to understand teaching practice of the teachers and develop research relationships with them. In the second phase, CAR was initiated and examined in terms of how it can promote the teachers' learning. A variety of data collection methods were used, including teacher interviews, classroom observations, group discussions, and a collection of materials. The constant comparative method was used for data analysis.

Results of the first phase indicate that teaching practice of the teachers was close to what is commonly referred to as traditional practice. They employed content-driven instruction and emphasized numerical physics problem solving, aiming to help the students to master test taking skills in order for them to enroll in desirable universities. They were very effective in classroom discussions in which students' idea contributions were limited, and also favored the use of behaviorist strategies for classroom control. Moreover, they exhibited some limitations in content knowledge including the nature of science. Based on interpretations of the teachers' conceptions of teaching that are somehow consistent with their prior school experience, it is argued that teaching practice of the teachers was a result of their attempts in compromising those conceptions of teaching with perceived contextual conditions.

Results of the second phase indicate that the teachers came to engage in CAR with a number of concerns related to their teaching practice; although concerns with self were less likely to be made explicit. Initially, the teachers might accept an instructional idea introduced to improve their teaching practice. However, they denied the idea later when they perceived that it did not meet their concerns. It was evident during the research that CAR must be adjusted to meet real concerns of the teachers, so that they can purposefully engage in CAR as they saw it relevant to them. If CAR were to capture their concerns, the teachers would learn meaningfully to improve their teaching practice.

The research demonstrates that CAR can be used to promote teacher learning in response to Thailand's education reform movement. Thus, promotion of its use should be done in other contexts. However, more systematic results of teacher learning experiences, in addition to anecdotal, from sustained CAR are needed.

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Luecha Ladachart
April, 2010

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

This chapter provides an introduction to the research. It begins with a background of the research, which is framed within an emphasis of Thailand's national development policy and its consequence on science education reform efforts. Then, the chapter discusses challenges experienced by Thai science teachers in responding to the national science education reform as well as drawbacks of current teacher development approaches. Next, the chapter delineates research questions and methods aimed to examine possibility and potential of using collaborative action research as an alternative approach to science teacher development in the research setting. At the end of the chapter, significance of the research is highlighted before a prompt of its limitations.

Background of the Research

Thailand experienced an economic crisis in 1997 as a consequence of its imbalanced development within which the economic aspect was developed rapidly while the social and educational ones were ignored (Laird, 2000; Pitiyanuwat and Sujiva, 2000; Fry, 2002; Sathirathai and Piboolsravut, 2004). A corollary after the economic crisis is serious reconsideration of ways to develop the country in a more gradual and holistic manner by emphasizing human development as a vital aspect (National Economic and Social Development Board [NESDB], 2001, 2007). During that period, one explicit action at the policy level was begun, resulting in the promulgation of the National Education Act (Office of the National Education Commission [ONEC], 1999), which now serves as a national framework of the education reform.

Along with the increasing awareness of human development, knowledge in science and technology was recognized as necessary for recovering the country from the economic crisis and further continuing development (NESDB, 2001, 2007). With this regard, human resources in science and technology can support the country to become self-reliant and be able to withstand the highly competitive global market (ONEC, 2002b). Hence, it is crucial for the country to educate its citizenry to acquire scientific and technological knowledge and be able to use it for management, conservation, and the utilization of natural resources and environment in a balanced and sustainable manner (ONEC, 1999). In addition, the citizenry should be able to engage socially in making informed decisions on science- and technology-related issues (Yuenyong and Narjaikaew, 2009).

As framed within the national education framework (ONEC, 1999) in general as well as the vision of "scientific literacy for all" (The Institute for Promotion of Teaching Science and Technology [IPST], 2002: 2) in particular, science education reform in Thailand has come to the forefront with its main focus to change the way of educating students from a didactic mode, which has existed traditionally, to a new one of active and meaningful learning by students (ONEC, 2004). By regarding students as ones who are "capable of learning and self-development" (ONEC, 1999: 10), science teachers have to facilitate a process by which each of them makes sense of natural phenomena in order to acquire related scientific concepts along with desirable skills and attitudes. Indeed, science teachers need to conceptualize knowledge as "actively constructed by and not given to" the students (Pillay, 2002: 14) or, in other words, to possess a constructivist epistemology (Dahsah and Faikhamta, 2008).

Besides, instead of following nationally prescribed curriculum and teaching manuals, science teachers need to organize subject content and "make it simple and enjoyable for children to learn" (Pillay, 2002: 15). This process of content transformation is guided by the National Science Curriculum Standards (IPST, 2002), but varies to school contexts in order to ensure that both national and local needs are fulfilled. Therefore, in doing so, science teachers with other school colleagues and community members have to make decisions on what and how particular science content should be taught in which grade. In addition to constructivist epistemology, this radically new task requires various knowledge domains (Magnusson, Krajcik, and

Borko, 1999) as well as changes in attitude (Atagi, 2002) for science teachers to be selective, creative, and autonomous in planning and implementing instruction.

Since facilitating a process of knowledge construction by individual students is an extremely complex task, by its nature depending on a number of factors (e.g., student, content, and context), science teachers are expected to use authentic assessment and carry out research to monitor and adjust their teaching practices to achieve intended instruction on a regular basis (ONEC, 1999). Using student learning as feedback, classroom-based research could provide them critical insights in order to cope with unique problems associated with instruction and from which to pursue particular interests for professional development. Ultimately, students will benefit from this kind of activity.

General Problem Areas

Once the education reform policy (ONEC, 1999) was legitimated, large-scale efforts to promote its implementation at the school level were begun under the label of "student-centered" instruction or the like (Pillay, 2002; ONEC, 2004). However, it has been apparent in general that Thai teachers, among other stakeholders, encounter difficulties interpreting what the policy proposes. Hallinger and Kantamara (2001: 401-402) described one well-known example as follows:

> … during the first year of implementing *student-centered learning* … the English term was translated into Thai as the equivalent of *learning where the student is the center-middle* (of the classroom). This translation caused much confusion about what *student-centered learning* was and what it should be in Thai culture. … After much controversy and discussion nationally, the official terminology was changed to the equivalent of *learning where the student is important*. (Italic in original)

Despite such a terminological change, the difficulties understanding and appreciating what the student-centered instruction means by in order to be implemented in the classroom continues to exist among Thai teachers. Atagi (2002: 51) noted one another example as follows:

> The "learner-centered approach" … is often single-mindedly misinterpreted as adopting a set of teaching devices such as field trips, group learning, discussions, and report writing … (instead of) a principle in which the importance is given to learners. (Quote in original)

It should be stated here that "even within the same household, the language of a teacher and the language of a professor of education may have little common ground" (Eisner, 1988: 19). Thus, such a superficial interpretation of the education reform intentions by many Thai teachers as merely changing instructional methods to be more activity-based may not be surprising. In part, this could involve teacher development in Thailand that relies mainly on authoritative top-down approaches aiming to introduce particular (mostly abstract) notions of reform-based practice to teachers without effective two-way communication (Fry, 2002; Pillay, 2002). As a consequence, many science teachers lack an ample understanding of student-centered instruction (i.e., constructivist epistemology), become suspicious of its effectiveness, and hesitate to change instruction (Dahsah and Faikhamta, 2008).

Until recently, the gap between the education reform policy (derived from research-based recommendations) and its implementation in science classrooms is still large. In other words, teaching of science in various Thai contexts relies heavily on didactic instruction with little, if any, change towards constructivist practice (Pongsophon and Roadrangka, 2004; Ratanaroutai and Yutakom, 2006; Ladachart and Roadrangka, 2008; Promprasit, Yutakom, and Jantrarothai, 2008). Moreover, many science teachers themselves are limited in content knowledge (Chamrat and Yutakom, 2008; Jantaraprasert, Roadrangka, and Noomhorm, 2008) and struggle with interpreting the national science curriculum standards to plan and implement instruction effectively (Dahsah and Faikhamta, 2008). This could result in student learning of science still being far from expectation (Pimthong and Yutakom, 2005; Ratanaroutai, Theeragool, and Yutakom, 2006; Nakthong, Anuntasethakul, and

Yutakom, 2007). In their recent review of science education reform progress, Dahsah and Faikhamta (2008: 298) reflected that "it will take a long time for teachers to shift their understanding and teaching practice towards constructivist-based views of teaching and learning."

Little progress of reforming science education at the school level calls for serious attention to current approaches to science teacher development. It is quite clear that presenting an abstract notion about reform-based instruction to science teachers and expecting them to implement it in the classroom as traditionally conducted is not enough (Goldenberg and Gallimore, 1991). Indeed, initiating reform-based practice involves not only individual teachers attempting to change instruction but also the broader cultural educational circumstance in which they work (Tobin and McRobbie, 1996). Therefore, on part of the teachers, a dialectical process of reconciliation among personal beliefs about teaching, recommended instructional change, and perceived contextual influences is essential to such an initiative (Briscoe, 1993). Although it is the responsibility for policy makers as well as educational academics to engage with teachers in that process, current effort seems to be adverse.

> … While the (National) Education Act suggests that the MOE (Ministry of Education) should adopt a more supervisory and coordinating role, there is still a mindset of control amongst many of the staff of the MOE (who) place emphasis on the inspection of teachers' work … the MOE staff will need training about this new mindset of supporting rather inspecting teachers. (Pillay, 2002: 24)

With such a new mindset, it is also crucial for the educational academics/researchers to situate themselves in school/classroom contexts—working closer and longer with teachers to support an initiative of desirable instructional change. A turn to collaborative partnerships between both traditionally separate groups may help reduce the gap between the education reform policy and its implementation or, at least, provide a better understanding of its existence. Ideally, in this new form of discourse, "these two groups of participants can learn new ways of thinking about their practices and … c(o)me away with new insights about teaching and learning" (Putnum and Borko, 2000: 9). This institutional collaboration will ultimately lead to the building of professional learning communities as demanded in an era of the education reform (Darling-Hammond and McLaughlin, 1995).

Research Questions and Methods

This research examines the possibility and potential of using collaborative action research (e.g., Baird, Mitchell, and Northfield, 1987; Feldman, 1996) as an alternative approach to science teacher development in a particular context of Thailand. It involves a group of physics teachers and the researcher working together to initiate possible actions in order to improve teaching practices as guided by the national science education reform policy (ONEC, 1999; IPST, 2002). In doing so, the teachers and the researcher engage reflectively and collaboratively to reconcile personal and contextual factors with the policy guidance in order to share, consider, and decide appropriate actions of improvement. Through "a process of shared reflection on theory and practice" (Baird *et al*., 1987: 136), it is likely that the researcher can facilitate the teachers to adjust their instruction towards constructivist perspectives and, in turn, get critical feedback from them.

In working with the teachers in a collaborative discourse, it is very important for the researcher to more or less understand their current teaching practices from their perspectives so he can sympathize a process by which the teachers harmonize (or fail to harmonize) their personal beliefs about science teaching with initiated instructional change under the given context. For this purpose, thus, the research is divided into two consecutive phases. The first one is devoted to understanding current teaching practices of each teacher while the second one involves a developmental process of their engaging and learning in collaborative action research. As a consequence, the two research questions are generated as follows:

1. How do the physics teachers conduct teaching practices in their given context?

2. How do the physics teachers engage in collaborative action research and learn to improve their teaching practices in response to the education reform?

To address the research questions, naturalistic inquiry (Lincoln and Guba, 1985) is used as a research methodology to collect qualitative data through a variety of methods including teacher interview, classroom observation, group discussion, and a collection of materials with minimized attempt to manipulate the research setting. In the first phase, the researcher begins to act as a non-participant observer in order to avoid his disturbance on teaching practices of the teachers; nevertheless, he gradually becomes more involved and develops a closer relationship with the teachers through interviews and informal conversation. Until the second phase at which collaborative action research is initiated, the researcher engages in it with the teachers as a facilitating member and as a participant observer using an emergent design to collect and analyze data in an ongoing, reciprocal manner—as one informs the other and vice versa—to generate working hypotheses. Through prolonged engagement and rapport, the researcher has access to credible data from the teachers. A number of techniques including peer debriefing, triangulation, and member checks are also used to ensure the creditability of the research results.

Significance of the Research

As outlined earlier, teacher development activities inclined to long-term collaboration between school teachers and university educators are quite new and rare in Thailand, particularly in local areas far away from universities. This is relatively opposed to an international trend that such collaborative partnerships have been established and sustained for ongoing learning by both teachers and educators (e.g., Erickson *et al*., 2005; Mitchell and Mitchell, 2008; Ryan *et al*., 2009). It is likely that the lack of collaboration in Thailand may in part limit or even prevent the progress of the national education reform. Hence, a momentum of such long-term collaborative research is needed. Here, a small-scale collaborative action research among a group of physics teachers and the researcher is established and examined. With its collaborative orientation, the research has significance in two domains.

First, the research entails insight into a process of reforming science education at the school/classroom level. In very general terms, it provides understandings of current teaching practices of the participant teachers as well as challenges they perceive in responding to the national science education reform policy. More specifically, within a collaborative discourse, the research describes a process by which the teachers each attempt to harmonize their teaching practices with constructivist instruction in their existing circumstance. These profound understandings are significant in terms that they guide to further the national science education reform efforts, especially on the science teacher development process, both in the context of research and elsewhere.

Second, it entails insight into the use of collaborative action research for teacher professional development in a particular context of Thailand. Although this notion is not new and widely documented in international literature (Roth, 2007), it “was never considered or encouraged” (Pillay, 2002: 33) in Thailand until a few recent efforts (e.g., Soonthornrojana, 2005; Naphatthalung, 2009) whose attentions were paid to a summative assessment of teacher knowledge about and attitude toward action research as well as the quality of their final reports. Here, a developmental process by which the participant teachers and the researcher engage in and learn through collaborative action research is more focused and documented. This information can serve those interested in initiating a collaborative research project in other Thai contexts.

Limitations of the Research

This research focuses on a developmental process by which a group of physics teachers and the researcher engage in and learn through collaborative action research in the particular context of Thailand. Despite recognition that teacher development research should not only pay attention to teacher learning but also subsequent student learning—i.e., the ultimate outcome (Hewson, 2007), this research is limited at the level of teacher learning only because of its duration. Indeed, it is unlikely to claim a significant outcome in student learning within a year of the research. Furthermore, based on its quality of naturalistic inquiry (Lincoln and Guba, 1985) as well as the uniqueness of action research processes (Somekh and Zeichner, 2009), the research is limited in terms of "transferability" of its results to other contexts. Readers have to determine the relevance of the research results in their own contexts.

Organization of the Dissertation

This dissertation is divided into six chapters. This chapter, Chapter I, has provided an introduction to the research, which includes background of the research, general problem areas, research questions and methods, significance of the research, and limitations of the research. In what follows, Chapter II is a review of the literature about Thailand's national development, the education reform and its related requirements, the educational system and curricular content in basic education, teacher development in Thailand, characteristics of effective science teacher development, and action research. Chapter III involves research methodology as well as collaborative action research as used in the study. Then, the research results are presented in Chapter IV and Chapter V according to the research questions respectively. Finally, Chapter VI offers conclusions and recommendations.

CHAPTER II

LITERATURE REVIEW

This chapter offers a review of the literature related to the study. It starts by highlighting the emphasis on human development in Thailand's national development plans as the original framework of the study. Then, the education reform and some of its related requirements are discussed. An overview of the educational system and curricular content is outlined for a contextual background. Next, the chapter turns to the focus of the study by discussing the importance of teacher development to the education reform, working approaches to teacher development, and appeals for an alternative approach in Thailand. In response to the appeals, characteristics of effective teacher development are discussed before action research is proposed as a potential option. The chapter then provides a review of action research, which includes its characteristics, its forms, and impacts on teachers engaging in it. At the end of the chapter, the use of action research in science education, the conduct of educational action research in Thailand, and suggestions about facilitation of teachers' action research are discussed.

The National Development

The Past National Development

Thailand experienced an economic crisis in 1997. Although many scholars have attempted to explain this economic crisis by suggesting its different underlying causes (Phongpaichit and Baker, 2000), it could be argued that the economic crisis was a consequence of an imbalanced development in the country. Before 1997, the country had experienced rapid economic development as a result of export-oriented policy while social and educational development lagged behind (Laird, 2000, Pitiyanuwat and Sujiva, 2000; Fry, 2002; Sathirathai and Piboolsravut, 2004). As a consequence, many of Thailand's citizens were not prepared enough to deal with or withstand the instability of global trend of the so-called modernization and eventually ended up suffering the disaster of the economic crisis. This is eloquently expressed by Laird (2000: 6):

> … Thailand was pursuing the global trend of financial liberalization ... tens of billions of dollars of foreign money flowed into the country ... But, with hindsight, it became very apparent that the Thai business and financial community lacked the capacity, the maturity, or the vision to use it wisely.

The lack of good preparation for Thai people to live in the economically competitive world also accelerate Thailand's encounter with environmental and social problems related to a lack of effective use and management of natural resources. These problems included a loss of terrestrial forest, industrial pollution, over-consumption of energy, poverty and inequity of people in the country, and illnesses resulting from industrial waste pollution (Sathirathai and Piboolsravut, 2004). In addition to these social problems, there was an increase in drug use, crimes, suicides, and depression among Thai people, particularly in youth (Atagi, 2002).

It became clear that the past national development—which overemphasized the economic aspect—was not one to achieve the country's goals. There was a need to rethink the style of national development that could reshape Thailand and make it more balanced and sustainable (Laird, 2000; Pitiyanuwat and Sujiva, 2000). Thus, human development becomes a key theme of the national development (NESDB, 2001, 2007), as the following section describes.

Human Development

Instead of emphasizing only economic development, human development has been considered as important for national development together with social, environmental, and political development (NESDB, 2001, 2007). Human development is however regarded as central to national development—the country is developed *by* and *for* human. The emphasis of human development has been recognized by national policies in term of education. Section 81 of the 1997 Constitution of the Kingdom of Thailand (OCS, 1997), for example, states the importance of education as follows:

> The State shall provide and promote the private sector to provide education to achieve knowledge alongside morality, provide law relating to national education, improve education in harmony with economic and social change, create and strengthen knowledge and instill right awareness with regard to politics and a democratic regime of government with the King as Head of the State, support researches in various sciences, accelerate the development of science and technology for national development, develop the teaching profession, and promote local knowledge and national arts and culture.

Besides this statement, other national policies such as the National Education Act (ONEC, 1999, 2002a) and the National Education Plan (ONEC, 2002b) have the aim of promoting education for all Thai people. These policies have led Thailand to the period of the education reform.

The Education Reform

As a requirement of the 1997 Constitution, the National Education Act B.E. 2542 (ONEC, 1999) and its amendments (ONEC, 2002a) were promulgated to serve as a fundamental educational law of the country. This promulgation was normally regarded as legislation for the education reform. According to the Act (ONEC, 1999: 3), a significant goal of the education reform is to lead Thailand to be “a nation of wealth, stability and dignity, capable of competing with others in the age of globalization.” In doing so, educational provision is placed on three principles: lifelong education for all, all segments of society participating in the provision of education, and continuous development of the bodies of the knowledge and learning process.

In the Act, there are many requirements of the education reform described in nine chapters, as the following shows:

1. General Provisions: Objectives and Principles
2. Educational Rights and Duties
3. Educational System
4. National Education Guidelines
5. Educational Administration and Management
6. Educational Standards and Quality Assurance
7. Teachers, Faculty Staff, and Educational Personnel
8. Resources and Investment for Education
9. Technologies for Education

The chapters emphasize ensuring basic education for all, learning reform, reorganizing educational administration and management, enhancing the teaching profession, mobilizing resources and investment for education, and promoting the use of technologies for education. However, learning reform is regarded as the most important aspect of the education reform (Atagi, 2002; ONEC, 2004). As a result, this research considers learning process reform, curricular reform, and enhancing the teaching profession to be the most relevant that promotes student learning of science.

Learning Process Reform

Learning process reform is needed to improve the instructional process from its traditional passive mode to the new perspective of active and meaningful learning. In this respect, students are no longer considered as knowledge receivers; rather, they are regarded as ones who are capable of learning and self-development, and the most important factor in the instructional process (ONEC, 1999). Therefore, the aim of the instructional process is to enable students to develop themselves at their own pace and to achieve the best of their potential in all aspects: physical and mental health; intellect; knowledge; morality; integrity; and to have a way of life that enables them to live in harmony with others (ONEC, 1999). Section 24 of the 1999 National

Education Act provides a set of guidelines that recommend that educational institutions should:

1. provide substance and arrange activities in line with the learners' interests and aptitudes, bearing in mind individual differences;
2. provide training in thinking process, management, how to face various situations and application of knowledge for obviating and solving problems;
3. organize activities for learners to draw from authentic experience; drill in practical work for complete master; enable learners to think critically and acquire the reading habit and continuous thirst for knowledge;
4. achieve, in all subjects, a balanced integration of subject matter, integrity, values, and desirable attributes;
5. enable instructors to create the ambiance, environment, instructional media, and facilities for learners to learn and be all-round persons, able to benefit from research as part of the learning process. In so doing, both learners and teachers may learn together from different types of teaching-learning media and other sources of knowledge; and
6. enable individuals to learn at all times and in all places. Co-operation with parents, guardians, and all parties concerned in the community shall be sought to develop jointly the learners in accord with their potentiality.

Moreover, it is stated in Section 26 of the National Education Act that learning assessment should be authentically embedded in the instructional process using a variety of methods with the aim at helping students learn and achieve their best. Based on these educational guidelines, learning process reform is widely promoted under the label of student-centered instruction (Pillay, 2002; ONEC, 2004), which is rooted in constructivist perspectives of knowledge acquisition (Dahsah and Faikhamta, 2008).

Curricular Reform

As a requirement of the education reform, reorganizing educational administration and management is placed on a principle of “unity in policy and diversity in implementation” (ONEC, 1999: 7). This is needed to decentralize educational authority from central organizations to local ones in order to serve the diversity in local contexts more relevantly and effectively. Curricular content, as an educational aspect, is thus required to relate to both national and local needs in order to prepare students to be literate globally and locally. Schools are responsible for prescribing curricular content related to the needs and contexts of their community. This notion is different from the past, when all schools implemented the same national curriculum prescribed by a central organization.

In order to develop a school-based curriculum, the Office of Basic Education Commission (OBEC) is responsible for prescribing the Basic Education Curriculum as national curricular guidance for schools (OBEC, 2001). The national curricular guidance (also referred to as the national or core curriculum) provides a framework of learning standards and anticipated learning outcomes at each educational level (the educational system is discussed in the next section). Based on this guidance, the schools need to develop their own curriculum consistent with the needs and contexts of the community in which they are located. Participation between the schools and the community is necessary for school-based curriculum development process.

Enhancing Teaching Profession

According to the 1999 National Education Act, teaching is considered as “a highly respected profession” (ONEC, 1999: 18). As professionals, teachers have major responsibilities for facilitating student learning through a variety of instructional methods with consideration given to students’ needs, interests, and potential. In other words, teachers are expected to deal with the diversity of students and the uniqueness of educational contexts to promote the most productive student learning possible. Thus, it is necessary for teachers to develop themselves and their own teaching practices in an ongoing manner. This expectation is stated in Section 30 of the 1999 National Education Act as follows:

> Educational institutions shall develop effective learning processes. In so doing, they shall also encourage instructors to carry out research for developing suitable learning for learners at different levels of education.

In addition to the enhancement of the teaching profession, teacher production and development systems necessarily need to prepare new teachers and develop in-service teachers continually and effectively.

Basic Education

The Educational System

The educational system in Thailand is categorized into three types: formal, non-formal, and informal (Office of the Education Council [OEC], 2006). Formal education specifies the aims, methods, curricula, duration, assessment, and evaluation conditional to their application inside the school system. On the other hand, non-formal education allows flexibility in determining aims, modalities, management procedures, duration, assessment, and evaluation outside the school system for people who do not enroll in the school system. Informal education enables individuals to learn by themselves according to their needs, interests, potential, readiness, and opportunities available from people, society, environment, media, or other learning resources.

Formal education is divided into two levels: basic and higher education. As defined in the 1999 National Education Act (ONEC, 1999: 5), basic education is "education provided before the level of higher education" with free of charge. It covers at least twelve years, divided into three years of lower primary education (Educational Level 1: Grade 1-3), three years of upper primary education

(Educational Level 2: Grade 4-6), three years of lower secondary education (Educational Level 3: Grade 7-9), and three years of upper secondary education (Educational Level 4: Grade 10-12) or three years of a certificate in vocational education.

In basic education, nine years of primary education and lower secondary education are compulsory (ONEC, 1999). After completing compulsory education, students who wish to continue their education have to decide to study either in upper secondary education or in vocational education. Upper secondary education provides students with basic knowledge, skills, attitudes, and personal attributes in order to study in higher education or at the university level. The certificate in vocational education provides students more competency-based schooling, specifying the standards of knowledge, skills, attitudes, and personal attributes for their future careers.

For higher education, students who completed upper secondary education can pursue a degree that may take four to six years in general. On the other hand, students who get a certificate in vocational education can take two more years for a related diploma in vocational education. Then, after getting a diploma, they can continue two more years for a higher diploma in vocational education that is equal to a degree from the university. Moreover, after getting a degree or a higher diploma in vocational education, higher education can also provide a master degree and a doctoral degree, generally requiring two years of study with a thesis and three years of study with a dissertation respectively.

Curricular Content

Section 23 of the 1999 National Education Act has outlined desirable attributes for all students (ONEC, 1999). According to this section, students are required to be knowledgeable about themselves and the relationship between themselves and society; knowledgeable about science and technology, mathematics, and language; knowledgeable about religion, art, culture, sports, and Thai wisdom; and have the knowledge and skills needed to pursue a career and to have a happy life. The Office of Basic Education Commission (OBEC) has prescribed the 2001 Basic Education Curriculum that all students at grade 1-12 are required to learn (OBEC, 2001). Content of the basic education curriculum include eight subjects: (1) Thai Language; (2) Mathematics; (3) Science; (4) Social Studies; (5) Health and Physical Education; (6) Art; (7); Career and Technology; and (8) Foreign Languages. All schools in basic education have to use these content areas as the national or core curriculum to develop their own school-based curriculum.

Science in Basic Education

According to Section 81 of the 1997 Constitution of the Kingdom of Thailand, the development of science and technology is important for national development (OCS, 1997). Thus, it is a responsibility of the country to educate all Thai people to be literate in science and technology (ONEC, 1999). Consequently, the 2001 Basic Education Curriculum prescribed science and technology as content that all students have to learn (OBEC, 2001). Scientific and technological literacy for all becomes a main national goal of education (IPST, 2002). All students are expected “to understand nature and man-made technological products and to use scientific knowledge reasonably, creatively, responsibly, and ethically” (IPST, 2002: 1). National policy states that human development in science and technology should increase the self-reliance of all people as well as enhance the competitive capacity of the country (ONEC, 2002b).

In promoting scientific and technological literacy for all, the Institute for the Promotion of Teaching Science and Technology (IPST) was established to be mainly responsible for promoting the teaching and learning of science, mathematics, and technology in the country. By collaborating with the OBEC, the IPST prescribed the national science curriculum standards, which is used and well-known as the “core science curriculum” for basic education (IPST, 2002). The core science curriculum describes the aims of the formulation of teaching and learning science as follows:

– To understand the principles and theories basic to science;

– To understand the boundaries, nature and limitation of science;

– To use skills to inquiry about and explore science and technology;

– To develop thinking processes and imagination, problem solving, and communicative and decision-making skills;

– To realize the influence and effects of the relationships between science, technology, people and environment;

– To use knowledge of science and technology to advance society and everyday life; and

– To be a human who has scientific attitudes, moral ethic, and value to utilize science and technology creatively.

In addition, the core science curriculum includes subject matter, learning standards, and expected learning outcomes. It is used by primary and secondary schools to promote student learning of science as part of their school-based curriculum.

In the national science curriculum standards (IPST, 2002), students learn science in a spiral manner—the students experience the curricular content repeatedly and in more sophisticated ways as they move into higher educational levels. The curricular content of science is presented in eight sub-strands: Living Things and Living Processes (sub-strand 1), Life and Environment (sub-strand 2), Matters and Properties (sub-strand 3), Forces and Motion (sub-strand 4), Energy (sub-strand 5), Processes that Shape the Earth (sub-strand 6), Astronomy and Space (sub-strand 7), and the Nature of Science and Technology (sub-strand 8). The last sub-strand, Nature of Science and Technology, can be integrated into other sub-strands. Students have to achieve the learning standards in each sub-strand at their educational level before continuing to the next higher level.

Physics in Basic Education

Physics in basic education strongly relates to sub-strand 4, Forces and Motion, and sub-strand 5, Energy. In sub-strand 4, there are two learning standards that students need to achieve. Students are expected to "be able to understand nature of electromagnetic force, gravitational force and nuclear force, have experienced investigative processes and communicate the knowledge acquired and make use of it correctly and morally and be able to understand types of motion of natural objects, have experienced investigative processes and possess a science mind, communicate knowledge acquired and make good use of it" (IPST, 2002: 7). In sub-strand 5, students are required to "be able to understand the relationship between energy and living, energy transformation, interaction between matter and energy, effects of energy utilization on life and environment, posses investigative skills, communicate knowledge acquired and make good use of energy" (IPST, 2002: 7).

More specifically for the upper secondary education with which this research involves, students in grade 10-12 are required to be able to:

– investigate, analyze and explain the relationship between force, motion of particles or objects in gravitational field, magnetic field, electric field, also make use of the knowledge;

– analyze and explain nuclear binding forces and forces between particles;

– experiment and explain relationship between displacement, velocity, acceleration in linear motion and perform calculations to find relevant quantities;

– investigate and explain simple harmonic motion, circular motion, projectile motion, also make use of them;

– investigate and explain properties of mechanical wave and relationship between frequency, wavelength and velocity of wave;

– investigate and explain sound making, sound intensity, sound quality, noise pollution and its effects on health and make use of sound;

– search for information and explain electromagnetic spectrum, also usefulness and dangers of electromagnetic wave;

– search for information and explain nuclear reactions, fission and fusion, interaction between matter and energy, benefits and risks of utilization on life and environment; and

– investigate, search for information and explain the original of radioactivity and its use, impacts on living things and environment (IPST, 2002: 18-22).

Facilitating student learning of science in line with the requirements of the 1999 National Education Act (ONEC, 1999) and of the National Science Curriculum Standards (IPST, 2002) is a great challenge for science teachers. Teacher development is a necessary factor to help them achieve such requirements.

Teacher Development in Thailand

Importance of Teacher Development in the Education Reform

Teachers have been widely recognized as very important in the education reform movement (Atagi, 2002; Fry, 2002; Pillay, 2002; Pitiyanuwat, n.d.). Their responsibility to facilitate student learning in line with the 1999 National Education Act is the most important aspect of the education reform (ONEC, 1999). Other aspects of the education reform (e.g., decentralizing educational authorities, assuring educational quality, enhancing teaching profession, mobilizing educational investment, and promoting technologies for education) can be considered as support for teachers to meet that responsibility. This was expressed by Hagreaves and Fullan (1992: ix) as follows:

> … we have come to realize in recent years that the teacher is the ultimate key to education change and school improvement. The

> restructuring of schools, the composition of national and provincial curricula, (and) the development of bench-mark assessments—all these things are of little values if they do not take the teacher into account. ... It is what teachers think, what teachers believe and what teachers do at the level of the classroom that ultimately shapes the kind of learning that young people get.

Thus, teachers—especially those who already are in service—are a high priority in the education reform (Pillay, 2002; Yutakom and Chaiso, 2007). The 1999 National Education Act (ONEC, 1999) recognized the need for teacher production and development as necessary for the education reform as stated in its Section 52 that:

> The Ministry (of Education) shall ... take a supervisory and coordinating role so that the institutions responsible for production and develop of teachers, faculty staff, and educational personnel shall be ready and capable of preparing new staff and continually developing in-service personnel.

This has led educational organizations to put forth a great effort to conduct teacher professional development in Thailand.

Working Approaches to Teacher Development

There are a number of educational organizations involved in teacher development in Thailand. These organizations include, for example, the Ministry of Education (MOE), the Office of National Education Commission (ONEC), the Office of Basic Education Commission (OBEC), and educational institutions (e.g., universities). More specifically, the Institute for the Promotion of Teaching Science and Technology (IPST) and the Science Society of Thailand under the Patronage of H.M. the King (SciSoc) also play important roles in science teacher development. These organizations conduct a variety of working approaches to teacher development, including teacher education programs, training courses, workshops, professional development programs, distance learning, and school-based training. Some of these teacher development approaches, however, can be integrated together in operation (e.g., Brahmawong, 1993; Petchurn, 2003).

Teacher Education Programs

As of 1997, Thailand had 114 educational institutions responsible for teacher preparation and development (Pitiyanuwat, n.d.). These are distributed throughout every region of the country. They are both government and private institutions that provide teacher education programs for both pre- and in-service teachers. Most of these institutions provide teacher education programs ranging from bachelor's to master's degrees while a few also offer doctoral degrees (Pitiyanuwat, n.d.). Kasetsart University, for example, has a wide range of degrees in its educational programs, including the Graduate Diploma (Science Teaching Profession), the Master of Arts in Teaching Science, and the Doctor of Philosophy in Science Education (Graduate of School Kasetsart University, 2009). The programs admit both practicing teachers and individuals who did not complete degrees in the educational field but would like to become teachers.

Curricula for teacher education programs are prescribed by the institutions as subjects for teachers to enroll in. These subjects generally include curriculum development, theories of teaching and learning, educational technology, educational administration, educational assessment, research methodology, and so on. Teachers enrolling in the programs are required to pass program criteria such as a minimum grade point average (GPA), qualifying or comprehensive examinations, a number of published articles in peer-reviewed journals, and proceedings in academic conferences. The program criteria in each program might vary, depending on the institutions and programs. The criteria could also include conducting research in the form of a thesis or dissertation with support from educational experts.

However, education in Thailand's universities have traditionally resembled "a knowledge-receiving culture," in which bodies of knowledge from outside, mostly

Western, countries are one-directionally transferred into the country without considering the Thai culture/society (Sinlarat, 2005). As a result, teachers who enroll in teacher education programs are not encouraged to be creative and productive for new knowledge but to be "the persons who seek for knowledge mostly be collecting from foreign sources (consumer and/or dependence) and teach/tell/lecture them to students" instead (Sinlarat, 2002: 141).

In addition, there are limitations regarding the regulations for admitting in-service teachers into education programs. As mandated by the Office of Basic Education Commission (OBEC, n.d.), for example, in-service teachers who desire to enroll in a regular program must be younger than 45 years old, have more than two years of teaching experiences, and enroll in a field consistent with their duty in the school. In addition to this regulation, not over five percent of all in-service teachers in each school are allowed to enroll in regular teacher education programs. Moreover, financial factors could be another problem for some in-service teachers who need support for their own education (Srisa-Ard *et al*., 2001).

Training Courses, Workshops, and Professional Development Programs

Training courses, workshops, and professional development programs are dominant approaches to teacher development in Thailand (e.g., Nitsaisook and Anderson, 1989; Hayes, 1997; Petchurn, 2003; Iemjinda, 2005; Promkatkeaw, Forret, and Moreland, 2007). According to Pillay (2002), this kind of teacher development approaches is conventionally conducted by the MOE, ONEC, OBEC, IPST, SciSoc, and the educational institutions. Its aims are generally diverse—for example, helping teachers to cope with practical problems, enhancing teachers' abilities to practice in particular ways, or introducing educational innovations to teachers—and its duration could vary (Yutakom and Chaiso, 2007). A follow-up evaluation of teacher practices after participating may be included as part of its activities in order to provide on-site support for teachers to deal with practical problems in real situations and also to get feedback to improve content and activities. In addition, teachers may be invited to participate in the program development process.

However, some limitations regarding this kind of teacher development approaches were reported. Pitiyanuwat (n.d.) argued that this kind of teacher development approaches is unsystematic, does not support all in-service teachers, does not pertinently serve teachers' needs, and rather emphasizes theory over practice. Regarding being unsystematic, it was also argued that the educational organizations responsible for teacher development do not share their framework and responsibility (Pillay, 2002). As a result, teacher development programs conducted by these organizations are fragmented and lack direction or focus. Furthermore, these organizations do not have enough capacity to provide support for all in-service teachers. Almost 700,000 in-service teachers in basic education (OEC, 2006) make it overwhelming for them. Moreover, because these organizations are conventionally central, most teacher development programs initiated by them are more likely not to serve teachers' needs.

Distance Learning

Distance learning is an alternative model of teacher development which mainly aims to support in-service teachers who have no access to the previously mentioned teacher development approaches (Yutakom and Chiaso, 2007). There are a number of in-service teachers—especially from rural schools—who cannot get away from their school because of the problem of distance and the shortage of teachers (Pillay, 2002). There are two types of distance learning programs. The first one is a broadcast using national satellite. It is called “Education Television Station” or ETV. In this service, teachers are expected to learn instructional strategies from television programs and apply them in their classroom (IPST, 2004). In addition, teachers are provided with learning resources that are available on internet. The second is a distance learning system provided by open universities (for example, see Brahmawong, 1993). This program allows in-service teachers to study by themselves through a set of integrated medias (e.g., reading materials, radio and video tapes, radio and television programs, and e-learning) without attending a conventional classroom (Sukhothai Thammathirat Open University, n.d.). However, this teacher development approach lacks ongoing two-way interaction and on-site support between learners (i.e., teachers) and lecturers. In addition to its limitations, this approach lacks of collaborative activities provided for teachers, and the teachers tend to not pursue their learning after getting a degree or certificate (Brahmawong, 1993).

School-Based Training

One rather new approach to teacher development in Thailand, when compared to those already discussed, is school-based training. It involves the identification and selection of a number of outstanding teachers to train and mentor other teachers. According to the Office of the Education Council (OEC, 2006), there are three types of outstanding teachers: national teachers, master teachers, and teachers of Thai wisdom. The national teachers are outstanding teachers who are able to conduct research and development on learning reform. They get financial support (220,000 baht/person/year) to do research as well as to disseminate and train a group of at least 50 teachers to apply their own research results within a three-year period. The master teachers are identified and selected as outstanding teachers who are able to practice student-centered instructions. They receive financial support (25,000 baht/person/year) to train and mentor at least 10 teachers in student-centered instruction within a four-month period. The teachers of Thai wisdom are local experts who are provided financial support to carry out three main tasks: mobilizing local wisdom in a school setting, integrating local knowledge into the school-based curriculum, and establishing local wisdom learning centers and networking.

The overall mentoring mode (national teachers, master teachers, and teachers of Thai wisdom) of teacher development is seen as school-based because those outstanding teachers can mentor their own colleagues who teach at the same or nearby school. Moreover, this approach focuses more on teachers' actual practices in their school and addresses teachers' needs. When compared to the previous approaches, the gaps between educational experts and teachers as well as that between theory and practice are likely reduced. Teachers can get this approach to teacher development in their school without leaving their students to attend workshops. This approach costs less than organizing workshops when targeting the same number of teachers.

However, there are some limitations to this teacher development approach. First, the number of outstanding teachers—26 national teachers and 586 master teachers (Puntumasen, 2004) — is short when compared to all in-service teachers. Second, most outstanding teachers can discuss and train other teachers only in a limited, specific area (Pillay, 2002). Third, training other teachers can considerably increase outstanding teachers' workloads and lead the outstanding teachers to leave their own classroom to be resource persons for other teachers (Amornvivat, 2002).

Appeals for an Alternative Approach to Teacher Development

Despite a number of working approaches to teacher development in Thailand, there are appeals for an alternative or supplementary approach to teacher development in response to the education reform movement (Pillay, 2002). The appeals highlight promotion of continued and empowered teacher learning (Fry, 2002) in order for teachers to become “knowledge producers” as well as “educational leaders,” who are active in improving their own practices and initiating the educational change, rather than “knowledge consumers,” who receive and implement educational innovations developed by others (Yutakom and Chaiso, 2007). In doing so, it is suggested that “teachers must be allowed to think and act (about teaching and learning)” (Amornvivat, 2002: 5). Moreover, there is a proposition to establish communities where teachers come to learn and share knowledge about teaching and learning (Atagi, 2002). Some responses to these appeals can be found in recent doctoral dissertations (e.g., Soparat, 2008; Juntaraprasert, 2009) that use “lesson study” as an approach to teacher development.

Characteristics of Effective Science Teacher Development

In international literature, it is suggested that teacher development is about enhancing teachers’ ability to learn to facilitate student learning. Teacher learning occurs best when it is initiated and sustained by teachers themselves (Bell and Gilbert, 1994), and no one can force teachers to learn or change (Clark, 1992). Teacher development thus involves creating a learning environment that promotes and motivates teachers to learn. In this section, the characteristics of effective environments that can promote science teachers' learning are summarized as a set of guiding principles that science teacher development should (1) be based on students' learning and help teachers to address students' learning difficulties; (2) be based on the needs of teachers both as individuals and as a group; (3) engage teachers in transformative learning experiences that confront their beliefs, knowledge, and habits of practice; (4) be integrated and coordinated with other initiatives in schools and embedded in curriculum, instruction, and assessment practices; (5) maintain a sustained focus over time and provide teachers with opportunity for continuous improvement; (6) actively involve teachers in observing, analyzing, and applying feedback to teaching practices; (7) concentrate on specific issues of science content and pedagogy and connect issues of instruction and student learning to the actual context of classroom; and (8) promote collaboration among teachers in the same school, grade, or subject. Each of these guiding principles will be discussed in turn.

Science teacher development should be based on students' learning and help teachers to address students' learning difficulties.

Teachers have a major responsibility to facilitate student learning (ONEC, 1999). Because of this, teacher development should not only be focused on teacher learning but student learning also. It is necessary for teachers to understand and be able to investigate how students learn, what difficulties or problems students experience when they learn particular content, and what alternative conceptions or prior knowledge they possess (Loucks-Horsley, Styles, and Hewson, 1996). Student learning should be viewed as the ultimate purpose of teacher development as Hewson (2007: 1181) said:

> … the ultimate purpose in providing professional development is the improvement of student learning. ... the connection between professional development activities themselves and student learning should also be included. ... it is necessary to expand the domain of professional development from a tidy, focused, coherent perspective on

> professional development activities and participants to include the complex, intertwined connection to student learning.

Science teacher development should be based on the needs of teachers both as individuals and as a group.

In a similar vein of promoting student learning, teachers are considered to be the most important factor in the teacher development process. As adult learners, it is necessary to take teachers' needs into account in teacher development activities. Teachers should be facilitated to self-develop based on their needs rather than be told prescriptively what they have to do in the classroom. In other words, teachers must have opportunity to control their own learning (Hewson, 2007). Bell and Gilbert (1994: 496) summarized their experiences of teacher development regarding teachers' needs as follows:

> … the teachers felt development was hindered if they were told by the facilitator to try a specific activity in the classroom ... They felt their development was supported if the facilitator gave them a range of activities to try out over the time ... They were then able to select which activity they would try, given then contexts in which they were teaching. ... The desired teacher development was not achieved by trying to force the teachers to change.

With regard to teachers' needs and readiness, it is also argued that the development of teachers is more likely to be maintained even in the absence of support from the facilitator (Bell and Gilbert, 1994).

Science teacher development should engage teachers in transformative learning experiences that confront their beliefs, knowledge, and habits of practice.

Teachers' beliefs can influence teachers' actions and also, in a broader context, the education reform (Cronin-Jones, 1991; Czerniak and Lumpe, 1996). Therefore, it is necessary for teacher development to deal with teachers' beliefs. Challenging teachers' beliefs could be a powerful way to encourage a restructuring of teachers' understanding of both learning and teaching (Loughran, 2007). Helping teachers to be aware of their beliefs and to understand their prior knowledge about teaching and learning can encourage them to change their practices (Wilson and Berne, 1999). With this in mind, teacher development should provide teachers with opportunities to confront their beliefs, prior knowledge, and habits of practice. Furthermore, teachers could be encouraged to compare and contrast their own beliefs with underlying principles of educational policies or instructional approaches.

> … teacher development is about helping teachers to critique beliefs underlying different educational policies and teaching approaches to clarify their own beliefs and commitments in science education and to act in ways congruent with their own beliefs and commitments (Bill and Gilbert, 1996: 37).

Science teacher development should be integrated and coordinated with other initiatives in schools and embedded in curriculum, instruction, and assessment practices.

The classroom is regarded as the best place to promote teacher learning (Thiessen, 1992). In a classroom, there are an abundant number of opportunities for teachers to learn to facilitate students' learning authentically. The classroom thus is not only a place of learning for students but for teachers also (Borko, 2004). Teacher development activities should therefore be school- or classroom-based (Thiessen, 1992; Abdal-Haqq, 1996). Teacher development, however, should not be seen as another additional task for teachers. Rather, it should be part of teachers' regular practices (Abdal-Haqq, 1996). Teacher development should be embedded in teachers' school life, which generally involves curriculum, instruction, and assessment practices. Reflection in and on teaching practices, for example, can enhance teachers' professional growth (Schon, 1983).

Science teacher development should maintain a sustained focus over time and provide teachers with opportunity for continuous improvement.

Meaningful learning generally is a slow and uncertain process for teachers (Borko, 2004). As a result, teacher professional development should be viewed as a lifelong or ongoing process (Abdal-Haqq, 1996; Loucks-Horsley *et al*., 1996). However, it is important for a teacher development project to maintain its focus over time in order to allow teachers to learn continuously. Duration with a sustained focus is an important factor for the teacher development project to promote teachers' learning (Garet *et al*., 2001). Additionally, teacher development should not create or increase teachers' dependency on those who initiate and support the teacher development project (Sachs and Logan, 1990). Rather, teachers should be empowered and be able to continue their own development by themselves as Bell and Gilbert (1994: 495) expressed.

> The teacher development process can be viewed as one of empowerment for on-going development, rather than one of continued dependency on a facilitator. The aims, activities, and facilitation of a programme were planned for teachers to feel empowered and not to continue to be dependent on the facilitator for their development.

Science teacher development should actively involve teachers in observing, analyzing, and applying feedback to teaching practices.

Teachers, like their students, learn best when they actively engage in learning process (Loucks-Horsley *et al*., 1996). Working on authentic problems can, for example, provide opportunity for teachers to conceptualize new knowledge connecting to their prior knowledge and beliefs and then transform it into further actions (Mark *et al*., 1998). Teacher development should therefore allow teachers to be involved actively in a learning activity related to their teaching practices. Active learning activities for teachers, for instance, could be observing other teachers' teaching, being observed by other teachers, and obtaining and sharing feedback from observations; collaboratively constructing lesson plans, implementing them in the classroom, and examining the implementation results; and giving presentations, leading discussions, and producing and publishing written work (Garet *et al*., 2001).

Science teacher development should concentrate on specific issues of science content and pedagogy, and connect issues of instruction and student learning to the actual context of classroom.

Teachers require many kinds of knowledge in order to facilitate student learning (Magnusson *et al*., 1999). They have to transform their content and pedagogical knowledge into a form or representation that is comprehensible for students (Shulman, 1986). In doing so, they also need to possess knowledge about students, curriculum, and the context of learning (Shulman, 1987). Teacher development should thus allow teachers to concentrate on what to teach, how to teach the contents, to whom the contents are taught, and the context in which teaching occurs (Abdal-Haqq, 1996; Louchs-Horsley *et al*., 1996; Wilson and Berne, 1999; Guskey, 2003). Additionally, teacher development should allow teachers to incorporate their variety of knowledge to instruction in their classroom. It is thus important for teacher development to focus on particular content that teachers will actually be teaching in their school rather than general and abstract ideas (Roth, 2007).

Science teacher development should promote collaboration among teachers in the same school, grade, or subject.

Promoting collaboration among teachers has been widely accepted as an effective way to do teacher development. Loucks-Horsley *et al*. (1996) suggested that teacher professional development should provide teachers with the opportunity to work in collaborative teams, to engage in discourse about content, teaching, and learning, and to observe the modeling of relevant, effective teaching strategies. Wilson and Berne (1999) also suggested that the opportunity to talk with others about subject matter, students and learning, and teaching can enhance teachers' professional knowledge and allow teachers to test, discuss, revise, and retry their own ideas related to instruction. Collaboration among teachers can be promoted through working together, observing and coaching each other, inquiring together into questions of common interest, and sharing what they learn from experiences (Loucks-Horsley *et al*., 1996). Collaboration with others can also promote teachers' social development (Bell and Gilbert, 1994).

Action Research

According to the national educational policies, the appeals for an alternative approach to teacher development, and the guiding principles of effective teacher development as discussed above, collaborative action research (e.g., Baird *et al*., 1987; Feldman, 1996) is being considered as a potential approach to physics teacher development. In this section, literature about action research will be discussed in order to provide a general sense for the conduct of collaborative action research. (Details of collaborative action research as used in this research are discussed in Chapter III.)

Action research is basically considered a form of research or systematic inquiry undertaken by practitioners on their own practices when they feel they have problems or are unsatisfied (Carr and Kemmis, 1986; Elliott, 1991; Altrichter, Posch, and Somekh, 1993; Noffke, 1997; McNiff and Whitehead, 2002). Practitioners generally conduct action research for many purposes such as solving practical problems, improving their own practices, creating understanding of practices as well as of situations in which practices occur, producing new practical knowledge, enhancing their own professional growth, influencing authoritative policies that shape their practices, and creating social positive change. Because action research involves practitioners' practices, it is agreed that practitioners have to play a key role in the action research process, during which they may or may not get supports from outsider experts or professional researchers. In order to understand the nature of action research, the characteristics of action research will be discussed.

Characteristics of Action Research

Action research is a practical-based and unique activity which requires a variety of methods.

Action research generally involves practical problems experienced by practitioners in their contexts. The involvement of practical problems in real-life situations makes action research unique intrinsically. For practitioners as action researchers, it is not possible to employ a rigorous method to deal with such unique problems. It is necessary for practitioners to conceptualize their problem reflectively in order to seek ways to solve or at least understand it (Schon, 1983). As a result, action research is considered a study of specific cases (Nixon, 1987), which require a set of methods. Action research can thus be considered a flexible methodology that can be used to cope with unique, practical problems (Capobianco and Feldman, 2006).

Action research is value-bound, socially-constructed, and historically-embedded.

There is a diversity of practitioners' perspectives on a particular situation. In other words, different practitioners can see a particular situation in different ways, depending on their values, prior experience, and the social and cultural framework in which they live. Some practitioners might consider a situation as problematic or unsatisfactory while others might not. As a result, action research, as a methodology that practitioners use to deal with their practical problems, is intrinsically value-bound (McNiff and Whitehead, 2002). Action research is conducted in order to improve the practice that is judged by practitioners' values. In addition, practitioners' values and practices have evolved through a social construction process over time. Thus, action research can be seen as socially constructed and historically embedded (Carr and Kemmis, 1986). Through a socially developmental process, practitioners can determine what counts as desirable or problematic, which is valuable or necessary for doing an inquiry or action research.

Action research is a participatory, collaborative, and democracy process.

As a value-bound, socially constructed, and historically embedded activity, participation and collaboration under democratic process are essential for action research. An attempt by a practitioner trying to solve a practical problem requires, to some extent, participation and collaboration with others. The practitioner necessarily needs to involve people to share their perspective on the problem, clarify the problem, investigate the problem, create and implement an action plan responding to the problem, observe and evaluate the action implemented, and reflect on and learn from the action. All these activities require all participants to be parts of and work together in action research. Through participation and collaboration, the participants attempt to seek ways to live together successfully (McNiff and Whitehead, 2002). Action research works through a democratic process in which all participants have the right to express ideas, debate critically and rationally, and make decisions on all its activities (Carr and Kemmis, 1986).

Action research involves reflective, critical, and emancipatory practice.

Because practical problems do not generally present themselves in an easily understandable form, practitioners need to be reflective in and on their action in order to solve the practical problems professionally (Schon, 1983). In doing action research, practitioners are required to reflect in and on their action in order to seek strategies to understand and solve the problems as well as learn from what they have done. Moreover, critical thinking is important for practitioners so that they can be aware of and understand the constraints that limit their own practices (Carr and Kemmis, 1986). These constraints can be both internal (e.g., their own belief, prior knowledge, and habits of practice) and external (e.g., cultural norm, organizational structure, and authority). Action research is a way that helps practitioners to overcome these constraints. Action research thus is a form of research that emancipates and empowers practitioners from such constraints.

Action research is a systematic and continuous inquiry.

Action research is conducted by practitioners in order to solve their own practical problems and improve their own practices. Practitioners can learn from what they have done through reflection. In this sense, action research is directed by practitioners' decisions about what counts as desirable or unproblematic practice and what counts as useful knowledge for them. What practitioners learn is interpreted through their own personal judgment, which could lead to misinterpretation. To prevent practitioners' misinterpretations and be convinced that their interpretation is valid and unbiased, it is necessary for them to conduct action research as systematically as possible. Practitioners need to provide evidence to support their claims whether their action is successful as well as how the knowledge they acquired from their action research can be valuable for others (McNiff and Whitehead, 2002). Practical problems are dynamic and there is no absolutely correct knowledge (Noffke, 1995). Practitioners need to solve their dynamic problems and improve their practices as an ongoing activity. Thus action research cannot be a static process, which starts with a question and ends up with an answer. Rather, it is a continuous process of improvement and development.

Action research starts with personal change but aims for social benefits.

Action research starts with a need to solve practical problems or improve practitioners' practices. The need is personally initiated by the practitioners' feeling of contradiction between what they value as good practice and what they actually do, which they want to improve even in little ways (Whitehead, 2000; McNiff and Whitehead, 2002). However, practitioners' improvement of practice should benefit not only practitioners themselves but also others who live in the same context. Action research brings all participants related to a practical problem to solve it together. Participation and collaboration among all practitioners create power for improvement and development, which eventually leads to social change, transformation, and benefits (Carr and Kemmis, 1986).

Forms of Action Research

As discussed above, there are many characteristics of action research. As a result, there are many names for it, depending on the characteristics emphasized in the particular study. Action research might be called participatory action research, collaborative action research, critical action research, emancipatory action research, or democratic action research, for example. Moreover, educational action research could be called teacher research, classroom research, or teacher inquiry. These different forms of action research reflect the important characteristics that are emphasized.

Participatory/Collaborative Action Research

Participation and collaboration are important characteristics of action research. Participation refers to sharing and taking parts (McTaggart, 1991, 1997) while collaboration refers to working together (Feldman, 1992) by participants in action research processes. Action research can thus be called participatory action research (McTaggart, 1991, 1997) or collaborative action research (Oja and Smulyan, 1989; Feldman, 1996; Capobianco, 2007) to emphasize the characteristics of action research in which all participants are working together and sharing benefits. In addition, it also implies practitioners' ownership of the improvement of their practices and the production of knowledge as a result of action research (McTaggart, 1991).

In a collaborative action research study, Capobianco (2007: 6), for example, explained participatory and collaborative characteristics among participants (i.e., teachers and a university researcher) in her study as the following: (a) mutually defining research problems; (b) collaboratively seeking solutions to research problems; (c) learning together from the research process; (d) sharing and shaping personal and critical reflections; and (e) sharing benefits of the action research results and contributing to others.

Democratic Action Research

Action research can be also called democratic action research (Jensen, Larsen, and Walker, 1995). In order to participate and collaborate in action research, it is necessary for all participants to create a democratic environment in which they have right to express their idea liberally and critically, rationally debate others' ideas, and make decision democratically in all action research activities (Carr and Kemmis, 1986). It can thus be said that democratic characteristics go hand in hand with participatory and collaborative characteristics of action research.

Critical Action Research

The name "critical action research" is used to emphasize critical characteristics of action research. It is conducted in order to increase social justice for all participants within the context of a critically oriented professional community (Tripp, 1990). Critical action research tends to be initiated and directed by practitioners who feel there is something unjust, problematic, or constrained about their practice under existing circumstances and who want to improve it. In doing critical action research, practitioners are required to articulate their existing circumstances as well as to be conscious of their world view, including values, aspirations, ideology, and habits embedded in their practice. Critical action research aims to develop new practice rather than to modify an existing one, which is constrained by their circumstance and world view.

Emancipatory Action Research

Similarly to critical action research, emancipatory action research emphasizes the characteristic of action research which empowers practitioners to overcome and be emancipated from both internal and external constraints that influence their practice. These constraints might be habits, customs, precedents, traditions, control structures, and bureaucratic routines, which practitioners feel are contradictory and irrational (Carr and Kemmis, 1986). However, emancipatory action research does not only involve individual’s critical thinking but also the common critical enterprise of changing. It aims to change or transform the institutions through practitioners’ participation and collaboration. As a result, participatory and collaborative characteristics are also important for emancipatory action research.

Teacher Research, Teacher Inquiry, and Classroom Research

Action research can be conducted by teachers as educational practitioners in order to create educational change (Elliott, 1991). As a result, action research conducted by teachers can also be called teacher research (Cochran-Smith and Lytle, 1993; Cox-Petersen, 2001; Roberts, Bove, and van Zee, 2007) or teacher inquiry (Clarke and Erickson, 2003). Through this name, the role of teachers as researchers (or inquirers) and teachers’ ownership of action research are emphasized. Furthermore, some who emphasize the context of educational action research—the classroom—might prefer to call action research “classroom research” (Ritchie, 1993).

Action Research as an Approach to Teacher Development

Action research can be viewed as an approach to teacher professional development as its process can foster teachers’ professional growth. It also shares the characteristics of effective science teacher professional development. Moreover, the conduct of action research is in line with Thailand’s education reform movement. These issues are discussed in this section.

Action Research and the Education Reform

Fostering teachers to conduct action research is strongly consistent with Section 30 of the National Education Act (ONEC, 1999), in which teachers are expected to carry out research to improve their teaching practices and promote student learning. It also espouses the three educational provisions of the education reform, which emphasize lifelong learning for all, participation among all stakeholders, and continuous development of bodies of knowledge and the learning process. Teachers who conduct action research can learn from their practices on a continuous basis. They and other stakeholders can participate and work together in an action research project focusing on a particular educational aspect. This could lead to a learning community where all stakeholders can contribute to and benefit from (Altrichter, 2005). Within such a learning community, there is the growing of a practical knowledge base as well as the development of the learning process.

Action Research and the Characteristics of Effective Science Teacher Professional Development

Action research unifies a number of educational activities (e.g., instruction, curriculum development, evaluation, educational research, and teacher professional development), which are often regarded as traditionally disparate (Elliott, 1991). In other words, all these activities can be seen as an intertwined form of action research that aims to translate educational values into concrete forms of teaching practices. When teachers teach, for example, they also conduct educational (action) research to evaluate student learning as well as their own teaching practices. Results of the evaluation provide teachers with information to develop or adjust the curriculum that has been implemented as well as improve their teaching practices. This intertwined activity, when continuously conducted, can be seen as a form of teacher professional development.

Thus, action research itself is related to student learning and also embedded in processes of curriculum development, instruction, and learning assessment in the classroom context. Teachers can conduct action research as part of their regular practices in order to foster students' learning and overcome their learning difficulties. Conducting action research allows teachers to focus on specific science content and/or pedagogy based on their values, needs, and interests. In addition, teachers have the opportunity to engage actively in the action research processes (e.g., planning, acting, observing, and reflecting), which allows teachers to confront and critique their own beliefs, prior knowledge, and habits of practice. Moreover, action research allows teachers to participate and collaborate with others who are involved with their action research study. Teachers can also sustain their action research study as an ongoing activity. Action research is a form of teacher development, which respects teachers' practical knowledge (van Driel, Beijaard, and Verloop, 2001).

Impacts of Engaging in Action Research on Teachers' Professional Growth

Action research has been diversely utilized in education such as in school-based curriculum development, professional development, school improvement programs, and systematic planning and policy development (Carr and Kemmis, 1986). In terms of teacher professional development, action research can be used to promote teacher learning by engaging in the research process. A number of action research studies have reported that engaging in action research can have several impacts on teachers, as discussed in what follows.

Teachers' Knowledge and Skills

By conducting action research, teachers can gain different kinds of knowledge and skills related to instruction. Knowledge and skills generally relate to the focus of action research that teachers conduct. For example, Goodnough (2008) reported that teachers have a clearer view and are more knowledgeable and comfortable about their curriculum when they undertake action research to eliminate redundancies and overlaps in the curriculum across levels. Tabachnick and Zeichner (1999) as well as Kang (2007) noted that collecting data from students while conducting action research helps teachers become more concerned about students' thinking and prior knowledge. Kang (2007) and Goodnough (2008) concurred that action research can help teachers apply new instructional strategies in their classrooms. Moreover, Briscoes and Wells (2002) commented that they, when becoming action researchers, are not only more reflective, analytical, and critical of their practice, but also increase their problem-solving skills.

Teachers' Confidence and Competence

An increase in teachers' knowledge and skills can help teachers feel more confident and competent to teach their students. Cox-Peterson (2001) as well as Briscoes and Wells (2002) agreed that action research results are empirical evidence helping teachers be more confident to make decision and undertake action in their classroom. Moreover, by engaging in action research, teachers are more confident about communicating their school problems and taking risks for solutions (Smulyan, 1987). Learning by solving authentic problems fosters teachers' trust in their own ability to solve their problem and construct their knowledge (Pedrietti and Hodson, 1995; Capobianco *et al*., 2006).

Teachers' Understanding of Research Processes and Connection between Theory and Practice

Conducting action research can foster teachers' understanding of what counts as research and what counts as action research (Feldman, 1994). In contrast to traditional educational research, action research presents an image itself in an understandable and usable form with a common language for teachers. As a result, action research can help teachers to see the theory-practice connection. In other words, action research reduces the gap between theory and practice for teachers (Goodnough, 2001; Papastephanou, Valanides, Angeli, 2005).

Teachers' Ability to Contribute Practical Knowledge to the Educational Field

Besides enhancing teachers' knowledge and skills in teaching and learning, it is also accepted that classroom-based knowledge produced from action research can contribute to the educational field (Pedretti and Hodson, 1995). van Zee, Lay, and Roberts (2003) argued that classroom-based knowledge is a form of knowledge that cannot be accessible by traditional educational research. Furthermore, sharing classroom-based knowledge among teachers can also create teachers' community of practice, which can contribute to both the practical and theoretical knowledge base in education (Capobianco and Feldman, 2006; Goodnough, 2008).

Decreasing of Teachers' Dependency on Educational Experts

There are many characteristics of action research that can foster teacher learning. Practical-based inquiry provides teachers with opportunities to learn actively through solving authentic problems. Participation and collaboration in action research can foster teachers' learning within a safe and supportive environment. Moreover, conducting action research on their own problems provides teachers with opportunities to learn and change at their own rate (Car and Kemmis, 1986). In addition, criteria for evaluating development are determined by teachers themselves rather than by outsiders. As a result, action research can be considered true self-development for teachers. It is a model of teacher development which does not rely much on educational experts (Papastephanou *et al*., 2005).

Action Research in Science Education

In science education, Feldman and Capobianco (2000) noted that action research has been utilized in three main domains: instructional processes, curriculum development, and teacher education or teacher development. However, it should be acknowledged that all three domains are interrelated and cannot be separated (Elliott, 1991). Using action research in science education generally involves encouraging teachers to conduct action research about the teaching and learning of science and curriculum development as well as facilitating teachers' development of their professional growth through experiencing the action research process.

There are some differences among these action research studies. Some action research studies are directed and driven by teachers themselves with support from a university researcher (Feldman, 1996; Capobianco *et al.*, 2006; Capobianco, 2007). In these studies, participants conduct action research in a context that is separate from their institutions and the power structures associated with the institutions. They come and join in action research on a voluntary basis, not dictated by district-based guidelines or mandated by administrators, educational consultants, or science educators. Action research is regarded as a way that can foster their own professional growth.

Some action research studies, however, are slightly different from the above. Participants in action research are not separated from their institutions or the power structures associated with the institutions. Rather, the participants conduct action research as part of the institutional activities and get support from their institutions (and sometimes from an outside-institution researcher). It is a form of action research in which the participants already working in the same institution agree to join and do an inquiry for a particular purpose. As a result, the participants do not leave their roles and status in the institutions in order to work collaboratively. Institutional relationship among the participants can be found. Hanuscin *et al*.'s (2007) and Goodnough's (2008) study are examples of this kind of action research.

Many action research studies are conducted as a part of a teacher education program (Pedretti and Hodson, 1995; Tabachnick and Zeichner, 1999; Cox-Peterson, 2001; Briscoe and Wells, 2002; van Zee *et al*., 2003; Kang, 2007). Teachers who enroll in a teacher education program conduct action research with the support and advice of a university researcher. The action research focus might be initiated by the teachers themselves (Briscoe and Wells, 2002) or introduced by the university researcher (Kang, 2007). Moreover, forms of collaboration are different, such as a teacher working together with a university researcher (Briscoe and Wells, 2002), or a group of teachers and a university researcher conducting individual action research projects which share some focus as a theme (Kang, 2007), or prospective and practicing teachers working together under the supervision of a university researcher (van Zee *et al*., 2003).

Educational Action Research in Thailand

Action research was initially conducted in Thailand before the education reform. Its focus, however, emphasized the promotion of students' learning rather than teacher development (Sukrangsan, 1991; Chayanuvat and Lukkunaprasit, 1997; Chuaprapaisilp, 1997). Encouraging teachers to do action research became more apparent after the promulgation of the 1999 National Educational Act (ONEC, 1999), which stated that teachers are expected to carry out research in order to improve their teaching practice and students' learning. Other requirements of the education reform (e.g., education for all and learning process reform) also stimulated teachers to conduct action research in response to those requirements. Conducting action research after the education reform has focused mostly on developing instructional activities to be more student-centered (Intasso, 1999; Kingmanee, 1999; Pongsamsuan, 1999), dealing with students' disruptive behaviors (Chumchuey, 2000), and extending learning opportunities for minority students (Nochai, 2000). Most of these studies were however conducted as part of teacher education program.

University researchers also play a role in promoting action research amongst teachers. They study teachers' experiences as they engage in action research as an approach to teacher development (e.g., Petchurn, 2005; Soonthornrojana, 2005; Anantasuchatkul, 2006; Naphatthalung, 2009) as well as curriculum development (e.g., Kajornsin, Chuaratanaphong, and Siengluecha, 1999; Sahasewiyon, 2004). Similarly to results in international literature, it is evidenced that engaging in action research activities can foster Thai teachers' development such as enhancing their thinking process, promoting their understanding of students, and increasing ability in preparing instruction. However, there are some obstructing factors for Thai teachers to conduct action research, including a lack of knowledge and understanding of action research, a lack of time, a lot of responsibilities in school, and a lack of resources and support (Chumchuey, 2000; Chimploy, 2001; Sinpo, 2003). As a result, it is suggested that teachers need support, such as training for understanding of action research, necessary resources, and facilitation from advisors or supervisors, and thus a school research-supported policy is necessary.

Facilitating Teachers' Action Research

Although engaging in action research can impact teachers' professional growth, teachers, especially in Thailand, might have difficulties conducting action research even if they wish to do so. It is argued that these difficulties involve a lack of understanding of action research, a lack of research skills, and a lack of support from their school (Chumchuey, 2000; Chimploy, 2001; Sinpo, 2003; Anantasuchatkul, 2006). As a result, it is difficult for teachers to do action research for their own development in their school (Johnston, 1994; Hancock, 1997). Carr and Kemmis (1986: 200) pointed to this challenge that:

> … one of the problems in educational action research is that people involved in education do not "naturally" form action research groups for the organization of their own enlightenment. (Quote in original)

Consequently, some intervention or facilitation for teachers to do action research at the beginning is necessary (Carr and Kemmis, 1986; Johnston, 1994). As shown in history, however, encouraging teachers to do action research is not an easy task. Some teachers might feel reluctant at first (Elliott, 1976-77; Hancock, 1997), see the facilitator as an outsider (Carr and Kemmis, 1986; Kemmis, 1988), and emphasize the technological domain of knowledge (Ponte *et al*., 2004; Anantasuchatkul, 2006). Moreover, roles of the facilitator in teachers' action research group as well as relationships between the facilitator and the teachers can influence the direction of the action research group and the development of teachers (Carr and Kemmis, 1986; Kemmis, 1988; Ponte *et al*., 2004). The outside facilitator may distort and overpower teachers' action research (Papastephanou *et al*., 2005).

> … The intervention of outsiders may introduce significant distortions in (teachers') action research … Indeed, it can be argued that some of what passes for action research today is not action research at all but merely a species of field experimentation or "applied" research carried out by (the outsiders) who coopt (the teachers) into gathering data

> *about* educational practices for them. … Forgetting the origins of action research, (the outsiders) have appropriated the term and carried out studies paradigmatically opposed to the nature and spirit of action research (Kemmis, 1988: 47). (Italic and quote in original)

Therefore, in this study, it must be remembered that the facilitator's task lies in helping teachers "get to where they want to get, not in 'getting' them to where the researchers think they should get to" (Kosmidou and Usher, 1991: 28) and "supply (the) teachers with a theoretical framework that is ancillary to the teachers' own theorization of action" (Papastephanou *et al*., 2005: 79). By this stance, the facilitator's roles are diverse and flexible—neither static nor definitive (Kosmidou and Usher, 1991; Pedretti and Hodson, 1995; Ponte, 2002; Goodnough, 2003, 2008).

Summary of the Chapter

This chapter has provided a review of Thailand's education reform, which highlights the importance of teacher development. It is discussed in the review that an alternative approach to teacher development is required, in addition to the working ones, in order to achieve the education reform requirements (e.g., a change in teaching practice towards student-centered instruction). Based on a review about characteristics of effective teacher development, it is argued that action research seems potential to be used for teacher development as it provides teachers and the researcher with opportunities to work together in order to improve their teaching practices. Nevertheless, this kind of research is rarely promoted and conducted in Thailand. In this study, "collaborative action research" whose term highlights collaboration among teachers and the researcher will be examined with the aim at promoting teacher learning in response to the education reform. The next chapter discusses research methodology as well as relevant features of collaborative action research as used in the study.

CHAPTER III

METHODOLOGY

This chapter is devoted to discussing the methodology employed in this research. The chapter is divided into five parts. The first part addresses the research paradigm used in this research, namely “naturalistic inquiry.” The second part overviews the research phases as initially designed. Then, the third part provides information about the research context as well as the research participants. In the fourth part, data collection and analysis methods are discussed. In the last part of the chapter, trustworthiness of the research is emphasized.

Research Paradigm: Naturalistic Inquiry

Research paradigm is referred to as a systematic set of ontological, epistemological, and methodological beliefs which are used by any researchers as criteria to determine how an object of inquiry is formulated and tackled theoretically and methodologically (Lincoln and Guba, 1985). In education, there are two different research paradigms most widely used to conduct research: scientific (or positivist) and naturalistic paradigm (Husen, 1997). The former is modeled after the natural sciences (e.g., chemistry and physics) emphasizing that the object of inquiry can be fragmented and made independent from the researcher to be studied. The latter is placed on a holistic view of the object of inquiry that is interrelated to the researcher and other things. As this research involves a group of teachers and the researcher engaging together in collaborative action research, the naturalistic paradigm is considered as relevant.

Naturalistic inquiry (Guba and Lincoln, 1981; Lincoln and Guba, 1985) is proposed against to prevalence of the scientific paradigm as an inquiry aiming to investigate social phenomena with minimized attempts to manipulate or control the context where they occur. It is based on an ontological assertion that a social phenomenon is embedded and has specific meanings in a particular context; therefore, it is unlikely to understand that social phenomenon in isolation from its context. Furthermore, it is also asserted that naturalistic researchers investigating a social phenomenon are unlikely to separate themselves from the context with the God's eye view. Neither can they break the phenomenon up into parts and nor absolutely avoid their influence on it. Rather, they must immerse themselves in and become part of the social phenomenon in order to understand it.

As naturally immerged in the research setting to investigate a social phenomenon, the naturalistic researchers regard themselves as the primary research instrument, instead of relying on the use of non-human instruments (e.g., paper-and-pencil tests), in order to gather data stemmed from field experiences of the social phenomenon being studied. It is argued that only the human instrument is sufficiently capable of grasping and evaluating meanings of the social phenomenon commonly embraced by a set of social values. In doing so, the naturalistic researchers use direct observations of the phenomenon, social interactions with other participants involving the phenomenon, and collection of artifacts generated in the phenomenon as main data resources. Then, they interpret or make meanings of the field experiences using both their tacit and explicit knowledge, and negotiate their interpretations with those made by the other participants.

In interpreting or making meanings of the data, the naturalistic researchers prefer an inductive process by which to discern patterns embedded in the social phenomenon being studied, rather than a deductive process of verifying a pre-formulated theory or proposition. This is because the naturalistic researchers are aware that they are investigating the social phenomenon in its natural (mostly complicated) context, so they can not know sufficiently well what kind of patterns are likely. Therefore, the inductive process of meaning making is normally conducted hand in hand with data collection as one informs the others and vice versa. Moreover, the naturalistic researchers allow the research design to emerge, instead of following a pre-designed research procedure, as they gradually better understand the patterns of the phenomenon being studied.

In attempts to investigate a social phenomenon, the naturalistic researchers aim to produce research results in the form of "working hypotheses" that describe the phenomenon. By working hypotheses, they are meant that the research results are bound intrinsically with time and context in which they are generated and that they may not be generalized in other times and contexts. (This is opposed to researches in the scientific paradigm aiming to make time- and context-free results that are able to be replicated in all times and contexts.) Therefore, utilization of the working hypotheses depends on similarity between the context in which the working hypotheses are generated (sending context) and the context in which the working hypotheses will be utilized (receiving context). Readers have to determine the relevance of the working hypotheses to be used in their receiving contexts. In helping them to do so, the naturalistic researchers are at best responsible to provide sufficient descriptions about the sending contexts. A mode of case reporting is considered as appropriate for this purpose.

There are strategies used by the naturalistic researchers to enhance credibility of the research results or the working hypotheses. For example, it is strongly recommended that the naturalistic researchers have to invest sufficient time to discern both common and salient patterns of the social phenomenon being studied, and to ensure that another salient pattern is unlikely to emerge. They should build trust and rapport with the other participants in order to share and negotiate different interpretations of the phenomenon. It is also very crucial for them to use multiple data sources to "triangulate" their current working hypotheses. Moreover, the naturalistic researchers are suggested to regularly expose the emergent process of the research with disinterested peers in order to test their taken-for-grant assumptions and develop more appropriate actions in the research setting. They are also required to record tracks of the research process to show how the research results have evolved. These strategies are used to ensure that the naturalistic researchers' personal bias are reduced or, at least, taken into consideration.

Given the fact that naturalistic inquiry aims to investigate a social phenomenon in a particular context in very natural manners, however it does not mean that the naturalistic researchers can do nothing to manage the research context in order to obtain a desired outcome. Rather, they can introduce positive elements into the context to increase possibility that the desired outcome will happen. Or, they can block negative elements that may exist in the context, leading to a lower possibility that the desired outcome will not occur. However, there is no guarantee that the desired outcome must happen under this kind of management. In the next section, attempts by the researcher of this study to introduce collaborative action research to the research context as a positive element to promote the national science education reform are described. Collaborative action research is expected to function as “a springboard” (Lincoln and Guba, 1985: 251) at which a group of physics teachers and the researcher begin to learn together to improve physics teaching practices.

Overview of the Research Phases

This naturalistic research aims to examine possibility and potential of using collaborative action research, where a group of physics teachers and the researcher come to work together to improve teaching practices in responding to the national science education reform policy, as an alternative approach to science teacher development. The research consists of two consecutive phases undertaken in each semester of the 2008-2009 academic years. The first phase is devoted to understanding teaching practices of participant teachers while the second phase involves a developmental process of their engaging in and learning from collaborative action research. An overview of the research phases, as initially designed, since the beginning of teacher recruitment is presented hereinafter.

Teacher Recruitment

At the beginning of the research (June 2008), the researcher recruited a group of physics teachers by sending an initial contact to three government secondary schools, using information from a pilot study (Ladachart and Roadrangka, 2008) that explored situations of teaching and learning sound at higher secondary level in a southern province of Thailand. The three schools were selected purposively based on "convenience sampling" (Patton, 2002: 241-242) because their nearby location allowed easy transportation and, then, could make collaboration among the teachers and the researcher more likely. The initial contact contains the significance of the research, research aims, and research questions. It was sent to each school, asking its principals to inform physics teachers interested in engaging in collaborative action research for improvement of their teaching practices to participate in the research. At the end of this process (approximately one month), there are four physics teachers from the three schools becoming the research participants. (Descriptions of them as well as their school context are provided in the following section.)

Phase 1: Understanding Teaching Practice of the Teachers

The first phase of the research was undertaken during the first semester (July to September 2008). It acted as the phase of "prior ethnography" (Corsara, 1980 cited in Lincoln and Guba, 1985: 251) at which the researcher primarily aimed to understand teaching practices of the teachers and develop research relationships with them before collaborative action research was initiated. Those understandings afforded "a baseline of cultural accommodation and informational orientation" (Lincoln and Guba, 1985: 251) for the researcher while collaboratively working with the teachers. It was this phase at which the researcher was prepared to be more likely to sensitize what happened during engaging in collaborative action research.

In doing so, the researcher immerged himself within contexts in which each participant teacher taught in order to gain understandings of their teaching practices. Without attempts to manipulate the research settings, the researcher acted as a non-participant observer to collect data through classroom observations with permission for video- and audio-recording and a collection of instructional materials. Based on an assumption that teaching practices of an individual teacher is a result of an ongoing process by which he or she has made meaning of experiences through involvement in the schools, each of the participant teachers' educational background, conceptions of science, and conceptions of teaching were also taken into consideration. These data were then analyzed using an interpretative process. (Data collection and analysis are discussed in detail at the end of this chapter.)

At the same time of attempts to understand teaching practices of the participant teachers, the researcher gradually developed research relationships with them through interviews and informal conversations. It was also expected that the teachers as well as their students gradually made themselves more familiar with qualitative research methods (e.g., being observed and recorded) and would act more naturally when collaborative action research was begun in the next semester. Despite the fact that development of human relationships between two people usually needs a long good time of interactions, only one semester is considered as appropriate for this research when its one-year duration was considered.

Phase 2: Engaging in Collaborative Action Research

After one semester of the first phase, the researcher initiated collaborative action research with the teachers. The use of collaborative action research is based on an assumption that knowledge is situated in the teachers' classroom experiences and can be acquired through critical reflection. Knowledge acquisition can be enhanced particularly when the teachers share their reflection with others. This assumption is radically different from that of the traditional teacher development approach that the teachers have to acquire knowledge from outside of the classrooms before applying it in the classrooms. Herein, relevant features of collaborative action research conducted in the second phase of the research (October 2008 – February 2009) are highlighted.

Reflective Feature

Collaborative action research is considered as a discourse where the teachers and the researcher come to meet on a regular basis in order to reflect on particular classroom situation(s) and share relevant perspectives. It is the discourse where the teachers and the researcher, with a range of experiences and perspectives, come to make meanings of the classroom situation in order to gain better or even new understandings of it. The meanings made will lead the teachers and the researcher to seeking appropriate actions to be taken for improvement of the classroom situation. Once some action is taken, its results are brought back by the acting teacher into the discourse for further reflection and improvement. Thus, an action-reflection cycle within the discourse became a key feature of collaborative action research.

Collaborative Feature

As in its name, collaboration is highlighted as a key feature of collaborative action research. It is embedded within a process of sharing reflection and perspectives on classroom situations as well as that of making collective decisions for appropriate actions to be taken. In this sense, collaboration could occur both among the teachers (Feldman, 1996) and between the teachers and the researcher (Baird *et al*., 1987). Both types of collaboration are preferable. However, the researcher tends to focus more on contributing "policy" and "theoretical" perspectives into considerations of the teachers. It is expected that those perspectives are likely to foster the teachers to better understand and then improve their classroom situations as it is framed at the outset that collaborative action research aims to improve teaching practices of the teachers to be more consistent with the national science education reform policy.

Evolutionary Feature

In initiating and embedding collaborative action research within the context of the teachers, it is very important to adjust its activities into the teachers' everyday school work which sometimes is already overwhelming. Since many action research models are prescriptive and "not necessarily representative of the realities" (McNiff and Whitehead, 2002: 52), following those models rigorously may disturb the teachers' work schedule and not create an environment that supports teacher learning. Based on this very fact, a generative transformational evolutionary process, as shown in Figure 1, is considered as appropriate in this research.

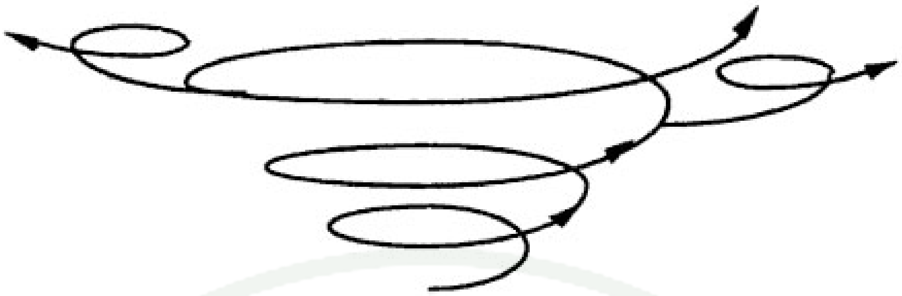

Figure 1 A generative transformational evolutionary process of action research
Source: McNiff and Whitehead (2002: 57)

McNiff and Whitehead (2002) propose this action research model as they consider it "more appropriate to the fluidity and unpredictability" (p. 52) of actual situations. They argue that "it is possible (for the teachers) to begin at one place and end up somewhere entirely unexpected" (p. 56). Therefore, the teachers are sufficiently flexible to pursue interests and understandings as emerged within the discourse. This model was successfully implemented in another local context of Thai teachers with little adjustments (Sahasewiyon, 2004).

Empowering Feature

Implicitly in all previously mentioned features of collaborative action research, the teachers are empowered to control content and process of collaborative action research discourse. Although the researcher has set a framework of collaborative action research to focus on the national science education reform policy, it does not mean that the policy guidance will only be the foci of the discourse. Rather, the policy guidance acts as a resource that could (or could not) help the teachers better understand their classroom situations. Indeed, the teachers are in charge of the discourse of collaborative action research.

Research Setting

The research took place in a southern province of Thailand. It is located over 800 kilometers far away from Bangkok by the main stream road. Its area covers almost 5,000 square kilometers besieged by nearby provinces and 120-kilometer long coast. The province consists of 10 districts. Its overall population is approximately 600,000 with a variety of religions (85% is Buddhist; 14% is Islamic; and 1% is Christian and others). Most population gain income mainly from agriculture, fishery, tourism, and some agriculture- and fishery-based industries. The income per capita is approximately 97,000 Bath. The province has 2 education service area offices; each covers 5 districts. In 2008, both education service area offices govern 311 basic education schools serving over 86,000 students. Survey data by the offices indicate that 100% of children population enrolls primary education, and 95% of those completed primary education continue secondary education.

The research was undertaken at the in the central district of the province, which is governed by the first education service area office. In this district, there are overall six secondary schools serving approximately 9,000 students (5,000 are 7-9 graders and 4,000 are 10-12 graders). Survey data by the office in 2007 indicate that higher secondary students in the district are university-bound; 99% completed secondary education continued to study at the university level and only 1% went to work. Only three of them, which are located 10-15 kilometers away from each other, involved the research. The normal organizational structure of all secondary schools in the district is based on two-semester system per year. Each semester takes approximately 18 weeks. Normally, the first semester spans from June to September while the second semester spans from November to February. The school system outlines holidays associated with religious days as well as Royal holidays.

Participants and Schools

Four physics teachers from three government secondary schools participated in the research. They included two experienced females, one beginning female, and one beginning male. Two of them (Mrs. Rattana and Ms. Jantra) were respondents of the pilot study, who showed interest to participate in the research. The other two teachers (Mrs. Darika and Mr. Sakchai) volunteered to participate after they knew about the research from their colleague. Descriptions of the teachers and their schools were provided using pseudonyms.

Mrs. Darika

Mrs. Darika was a physics teacher in a school whose vision is “enhancing students' ability in science, technology, and environment” (School Website, 2008). In the 2008-2009 academic years, student population was approximately 1,150. The school consisted of 15 lower secondary (grade 7-9) classes and 15 higher secondary (grade 10-12) classes. All higher secondary classes were science stream, emphasizing on science and mathematics. A number of students per class were fixed at 36. There were 65 teachers in the school including 16 science teachers (10 females and 6 males). Mrs. Darika is one of five physics teachers (2 females and 3 males). In addition, there are laboratory boys/girls who have responsibility to prepare and maintain laboratory equipment for science teachers and be teaching assistants, if requested, during class hands-on activities. The school had a wide range of facilities such as air conditioners, televisions, overhead projectors, laboratory rooms, computer rooms, a library, and sport equipment.

Mrs. Darika was 52 years old with a bachelor degree in education (physics teaching). She had taught science in lower secondary level for 26 years and received a reward as an outstanding teacher (so-called specialist or *Kor-Sor-Sam* teacher). At the time the study started, it was her fifth year of physics teaching. She taught grade 10 physics, grade 11 science project, and non-science subjects (Boy Scout and homeroom), resulting in 16 fifty-minute periods of teaching load per week. Besides teaching, she had responsibility to keep records of uses of equipments and materials in the school. During last two years, she attended a professional development program about doing classroom research. As an outstanding teacher, she was selected by the education service area office to assess other science teachers’ classroom research.

Mrs. Rattana

Mrs. Rattana taught in a long-standing school whose vision is "educating students to have habits of learning, virtue, morality, and desirable characteristics" (School Website, 2008). In the 2008-2009 academic years, student population was approximately 2,700. The school consisted of 33 lower secondary classes and 33 higher secondary classes. Twenty-four higher secondary classes were science stream while the other nine classes were non-science stream, emphasizing on social studies, language, and art. A number of students per science-stream class were approximately at 47. There were 111 teachers in the school including 15 science teachers (9 females and 6 males). Mrs. Rattana was one of five physics teachers (3 females and 2 males). The school had adequate facilities such as fans, laboratory equipments, computer rooms, a library, and sport equipment.

Mrs. Rattana was 36 years old with a bachelor degree in education (physics teaching) and a master degree in science education (physics). She had 14 years of physics teaching experiences; 12 years in a rural secondary school and 2 years in the present school. At the time the research started, she taught grade 10 physics and grade 12 physics, resulting in 16 fifty-minute periods of teaching load per week. Besides teaching, she had responsibility to keep records of student information. During last two years, she attended a professional development program about informal science teaching, authentic assessment in science, and doing classroom research.

Ms. Jantra

Ms. Jantra taught in a school established to serve increasing population in the province. Its vision is "developing students in according to the educational standards based on being Thai" (School Website, 2008). Student population was approximately 1,400. The school consisted of 18 lower secondary classes and 15 higher secondary classes. Five secondary classes were science stream while the other ten classes were non-science stream. A number of students per science-stream class were approximately at 46; however, one class had 51 students. There were 57 teachers in the school including 7 science teachers (5 females and 2 males). All two physics teachers in the school participated in this study. The lack of science teachers was limitation of the school, resulting in a smaller ratio between science-stream and overall classes than that of the other two schools. The school had some facilities such as computer rooms, library, and sport equipment; however, it was inadequate in laboratory equipments.

Ms. Jantra was 26 years old with a bachelor degree in science (physics) and a diploma degree in science teaching. She was a scholarship student in the Project for the Promotion of Science and Mathematics Talented Teachers (PSMT[1]) supported by the IPST. She started her teaching profession for one and a half year. She taught grade 8 science, grade 10 physics, grade 11 physics, and non-science subjects (Boy Scout and homeroom,) resulting in 20 fifty-minute periods of teaching load per week. Besides teaching, she had responsibility to provide students advices for future education as well as seek financial supports for them. During last two years, she attended a professional development program about a 5Es inquiry cycle, authentic assessment in science, and doing classroom research.

Mr. Sakchai

Mr. Sakchai taught in the same school as Ms. Jantra. He was 25 years old with a bachelor degree in education (physics teaching). He had 2 years of physics teaching experiences; 1 year in the same school as Mrs. Rattana and 1 year in the present school. As the school lacked of science teachers, he worked in the school as a non-government teacher under a year-by-year contract. He taught grade 9 science, grade 10 physics, grade 12 physics, and non-science subjects (Boy Scout and homeroom), resulting in 21 periods of teaching load per week. Besides teaching, he worked in the academic department of the school with no specific tasks; he had to do all of what he was requested to do. During last two years, he attended a professional

[1] PSMT is a project for the Promotion of Science and Mathematics Talented Teachers launched by the IPST. It provides a five-year scholarship for students who complete secondary education and plan to be science or mathematics teachers. Students take four years for a bachelor’s degree in science or mathematics and one year for a teaching diploma.

development program about a 5Es inquiry cycle and doing classroom research.

Data Collection

As previously mentioned, the naturalistic researchers including the one of this research regard themselves as the primary research instrument to explore and understand a social phenomenon while they are in the research setting. In doing so, they can utilize some particular methods to acquire data from both human and non-human sources. In this research, the researcher used teacher interviews, classroom observations, and group discussions to obtain main data from the human sources. He also collected documents used in classroom activities (e.g., instructional materials and copies of student work) as well as informational residue (e.g., posters in the classrooms) to get additional data from non-human sources. Moreover, he regularly kept journals during the research and asked the participant teachers to do the same, so the journals were used as supplementary data. In this section, each data collection method is overviewed before its specific use in each research phase is detailed.

Interview

Interview is defined as a conversation with a purpose (Dexter, 1970 cited by Lincoln and Guba, 1985: 268). It has been used widely in educational research for many purposes (Lincoln and Guba, 1985; Keats, 1997; Patton, 2002). Basically, it is used to understand a social phenomenon from perspectives of research participants; it unfolds meanings that the research participants made from their experiences of the phenomenon. In this research, interviews are used to understand what the teachers do in their classroom and why they do that from their perspectives. That is, through the interviews, the researcher can have access to the meanings of the teachers' classroom actions. In addition, the interviews are used to portray the past experiences of the teachers. They are also used to check credibility of the working hypotheses or the research results with the teachers as well as to be used for doing triangulation with other data (Lincoln and Guba, 1985).

There are many types of interviews based on how they are conducted. The main distinction is placed however on its structural continuum. According to Lincoln and Guba (1985), the structured interview, where the interviewer knows what he or she does not know and can formulate an appropriate series of questions to find it out, is placed on one end of the continuum. The interviewee is expected to answer those questions in terms of the interviewer's framework. On the other end of the continuum, the unstructured interview is a mode of interview in which the interviewer does not know exactly what he or she wants to say or elicit. Thus, questions emerge from the immediate context and flow naturally as a process of interaction or communication between the interviewer and the interviewee. The semi-structured interview is placed between the two ends of the continuum where its conversational content depends on the interviewee's responses to an issue or issues broadly raised or outlined by the interviewer (Patton, 2002).

In addition to the structural distinction, interviews can be classified depending on their degree of overtness (Lincoln and Guba, 1985). A covert interview is a mode of interview where the interviewee does not know he or she is being interviewed or does not know the true purpose of the interview while an overt interview refers to the opposite (Guba and Lincoln, 1981). The interviewer thus has to decide to what extent the interviewee should be informed about the purpose of interview based on ethical principles and the degree of distortion that might occur when the purpose of the interview is overt. Moreover, an interview can be classified into many types based on the relationship between the interviewer and the interviewee (either positive or neutral or negative). Furthermore, an interview can be conducted by either a team of interviewers or an individual interviewer who might interview either a group of respondents or an individual one.

Interviews are conducted differently and the format can change over time depending on their purpose, manner, and the interviewees (Patton, 2002). For example, an unstructured interview might be conducted overtly in order to understand the teachers’ perspectives of their own actions in their classroom while the structured interview might be conducted covertly, to some degree, in order to triangulate with other data. The researchers can combine different interview approaches while conducting an interview (Patton, 2002). For example, they might prepare some exact questions for interviewing some aspects as well as generate questions spontaneously for other aspects while the interview is being conducted. In this research, interviews will usually be unstructured and overt because the teachers and the researcher work closely and collaboratively in natural settings. Ideally, the researcher and the teachers could consider one another as peers when conducting interviews.

Observation

Observation is a powerful research method that the naturalistic researchers immerse themselves in the context in which a social phenomenon being studied occurs. Being naturally in the research context allows the naturalistic researchers to have "here-and-now experience" (Lincoln and Guba, 1985: 273) of the social phenomenon being studied, so they are likely to develop deep understandings of its context. In this regard, the naturalistic researchers who become a part of the phenomenon are likely to grasp "motives, beliefs, concerns, interests, unconscious behaviors, customs, and the like" (Guba and Lincoln, 1981: 193) shared by those participating in the phenomenon. Moreover, observations allow the naturalistic researchers to seek addition related information from other data sources within the context (Patton, 2002). Similarly to the interview, observations can be classified into many types along a continuum, depending on the criteria used.

Based on the degree of participation, for example, observations can be considered on a continuum between participant and non-participant (Lincoln and Guba, 1985). On one end of the continuum, there is participant observation, where the naturalistic researchers participate and do activities as a member of the group while conducting observation. They have two roles as both observers and participants simultaneously. Through this emic mode, the researchers are allowed to experience events and behaviors with insiders' eyes, even though it might be unlikely for them to capture all events and behaviors happening in the context. On the other end of the continuum, non-participant observation, the researchers play only the observer role.

The researchers keep a distance away from the participants and observe them in order to avoid observational disturbance—although, as asserted in the naturalistic paradigm, interaction and influence between the non-participant observers and those being observed still inevitably exists. The researchers can observe events and behaviors with a broader view when compared to participant observation. Nevertheless, the researchers can experience events and behaviors with outsiders' perspectives (the etic mode).

Observation can also be placed on the overt-covert continuum (Guba and Lincoln, 1981). On the overt side of the continuum, the researchers could ask permission and fully inform the participants about the observation. Conversely, on the covert side, the researchers could pretend to be a participant in the group without any announcement and, at the same time, observe what is happening in the group. Like an interview, the researchers have to make decisions about their observational role as to what extent it should be overt, based on ethical principles and the degree of distortion and influences that might occur when the participants know they are being observed. Guba and Lincoln (1981), however, asserted that it is occasionally impossible to observe the participant without their awareness, cooperation, and consent. As a result, overt observation with trust and rapport between the researchers and the participants is recommended (Lincoln and Guba, 1985).

In addition, observation can be placed on the structured-unstructured continuum (Guba and Lincoln, 1981; Lincoln and Guba, 1985). Structured observation is a systematic mode in which the researchers know what they do not know and try to observe it in advance based on a conceptual framework formulated before observations are conducted. Structured observation mainly aims at verification. On the other hand, unstructured observation is a less systematic mode in which the researchers do not fully know in advance what they want to focus on or pay attention to. Rather, the researchers broadly observe events and behaviors in order to seek or discover salient features happening in the context. Structured and unstructured observation might thus relate to narrow-focus and broad-focus observation respectively (Patton, 2002).

Observations are conducted diversely and can change over time, depending on the purpose and situation. Participant observation, for instance, could be conducted when the researcher and the teachers are engaging in collaborative action research because in that situation the researcher has to play roles of both the facilitator and the researcher simultaneously. On the other hand, non-participant observation might be conducted when the researcher visits the teachers' classroom and observes their teaching practices in order to avoid disturbance or make an influence on student learning. However, both group meetings and classroom observations are overt and the teachers and their students are informed of the research purpose. Unstructured observation might be conducted in the early stages of the study. More structured observation could later follow when the researcher has some working hypotheses and needs to investigate them in advance. Observations are flexibly conducted in order to "yield the most meaningful data" (Patton, 2002: 267) based on ethical principles.

Nonverbal Communication

During interviews and observations, the naturalistic researchers also pay attention to nonverbal communication. According to Guba and Lincoln (1981), nonverbal communication is defined as "the exchange of information through nonlinguistic signs" (p. 215) such as body movements, gestures, body-orientation, facial expressions, timing, physiological signs, reaction pacing, and implicit verbal indicators. These could provide the naturalistic researchers with a sense of the relationship between them and informants, the relationship among research participants, and the informants' feelings about themselves. However, because interpretations of nonverbal communication can vary depending on the researchers' inference and the informants' cultural values and beliefs, nonverbal communication has to be used as a supplement to other data collection methods rather than an independent one. It is used to test for dissonance against data from other sources.

Related Documents and Unobtrusive Informational Residues

In naturalistic inquiry, related documents are useful sources of information (Lincoln and Guba, 1985). Even though they are less reactive than human sources, they are often available at a low cost, stable and legally unassailable, and contextually rich and relevant. Related documents can be classified into many types depending on the criteria used. The main distinction is their source, which can be divided into primary and secondary (Lincoln and Guba, 1985). Primary documents are referred to as documents that are generated from firsthand experiences of a particular situation, while secondary ones are like hearsay later generated from primary documents. In addition to their types, related documents can be viewed as solicited and unsolicited; comprehensive and limited; edited and complete or unedited; anonymous and signed or attributable; and spontaneous and intentional (Guba and Lincoln, 1981).

Unobtrusive informational residue is an alternative choice of data sources that can be used by the naturalistic researchers. According to Lincoln and Guba (1985: 279-180), unobtrusive informational residue refers to "information that accumulates without intent on part of either the researchers or the teachers to whom the information applies." These kinds of data sources can be used in a manner that reduces reactivity and sensitivity that might otherwise occur as a result of measurement (Guba and Lincoln, 1981). Physical traces (e.g., learning resources available in the school) can be used as indicators or additional information related to a teacher's teaching practices or instructional activities, for example. Both related documents and unobtrusive informational residue can be used to triangulate with other data sources.

Field Journals

The naturalistic researchers often keep field journal during being in the research setting. The field journals include a log of day-to-day activities, a personal log, and a methodological log (Lincoln and Guba, 1985: 281). The log of day-to-day activities is like a calendar of appointment noting what the naturalistic researchers do at a particular time, day, and place. The personal log is used by the naturalistic researchers to reflect on their notions, feelings, states of mind, and expectations in relation to what is happening in the research setting. In addition, the personal log is used by the naturalistic researchers to show an awareness of their own bias and to note working hypotheses emerging in their mind. The methodological log is utilized to record all methodological decisions made in accordance with the emergent design. It can be used for tracing how the research results or the working hypotheses have been evolved.

Group Discussion

In addition to data collected by the methods mentioned above, conversations within the discourse of collaborative action research among the participant teachers and the researcher are used as main data addressing in particular to the second research question. It is the data from the teachers' contributions to the discourse that allow the researcher to focus upon how the teachers engage in and learn from collaborative action research. Moreover, the data from the group discussions can be used to triangulate with other data collected by other methods.

Data Collection in Phase 1

In the first phase of the research, the researcher aimed to understand teaching practices of the participant teachers before collaborative action research between him and the teachers was initiated. This phase was undertaken in the first semester of 2008-2009 academic years during July to September 2008. The researcher began to collect data related to teaching practices of the participant teachers using individual semi-structured interviews about their educational background, their conceptions of teaching, and their conceptions of science. Data from the interviews were considered as meanings about science teaching that the teachers each have constructed based on their experiences in the school of science. Then, the researcher used the interview data were as a referent while observing teaching practices of the teachers. In this regard, the researcher was likely to understand teaching practices of the teachers from their perspectives (the emic mode).

In doing so, the researcher developed interview items (see Appendix A) in order to obtain data related to the teachers' educational background, conceptions of teaching, and conceptions of science. Before the interviews, the teachers were informed the purpose of the interviews and encouraged to provide information as much as possible without feeling of being evaluated. Their permission for audio-recording was also asked for reviewing and transcribing. The interviews of each teacher were conducted two times in order to make its duration not too long. The first interview focused on educational background and conceptions of teaching, while the second one focused on conceptions of science. All of the interviews were undertaken at the teachers' lounge during the school time except Mr. Sakchai's first interview that was undertaken after the school time at his residence. Each of the first interviews took 30-50 minutes except the one of Mrs. Darika taking over one and a half hours since she was very enthusiasm to provide personal information. The second interview of each teacher took shorter time than did the first one. This was because the teachers were less confident to express their conceptions of science; some of them sometimes denied doing so. Details of the interviews are outlined in Table 1.

Table 1 Details of interviews about the teachers' educational background, conceptions of teaching, and conceptions of science

Teacher	Interview	Date	Place	Time (min)
Darika	First interview	July 8th, 2008	School	92
	Second interview	July 29th, 2008	School	32
Rattana	First interview	July 10th, 2008	School	34
	Second interview	July 25th, 2008	School	17
Jantra	First interview	July 14th, 2008	School	38
	Second interview	August 5th, 2008	School	32
Sakchai	First interview	July 9th, 2008	Home	50
	Second interview	July 30th, 2008	School	14

In addition to the initial interviews, the researcher aimed to visit the teachers' classroom on a regular basis in order to observe their teaching practices. In doing so, the teachers each were asked to select one of their physics classes with which they were most convenient and comfortable for persistent classroom observations. As a consequence, Mrs. Darika, Mrs. Rattana, and Mr. Sakchai selected their grade 10 physics class while Ms. Jantra preferred her grade 11 physics class. With agreement between the teachers and the researcher, classroom observations for each teacher were initially planned to be undertaken at least once a week. However, due to school activities, student learning assessments, and teacher conferences, some of the planned classroom observations were skipped by the teachers while a few unexpected ones were added. As a consequence, there were a different number of classroom observations among the teachers. Table 2 outlines details of classroom observations undertaken for each teacher. Most classroom observations took two periods (100 minutes), but a few took one period.

Table 2 Classroom observations undertaken in the first phase

Teachers	Total Number	Classroom Observations		
		Date	Period	Key Content
Darika	6	July 23rd, 2008	2	Classical mechanics (e.g., one-dimension motion, Newton's laws, friction, and mechanical equilibrium)
		August 4th, 2008	2	
		August 11th, 2008	2	
		August 25th, 2008	2	
		September 1st, 2008	2	
		September 8th, 2008	2	
Rattana	5	August 7th, 2008	2	Mechanical equilibrium
		August 14th, 2008	2	
		August 28th, 2008	2	Wave/ Heat
		September 4th, 2008	2	Radioactive decay
		September 10th, 2008	1*	Nuclear reaction

Table 2 (Continued)

Teachers	Total Number	Classroom Observations		
		Date	Period	Key Content
Jantra	7	August 5th, 2008	2	Temperature, heat, and gas behaviors
		August 19th, 2008	2	
		August 26th, 2008	2	
		September 9th, 2008	2	Wave and its properties
		September 15th, 2008	1	
		September 16th, 2008	2	
		September 23rd, 2008	2	
Sakchai	5	July 30th, 2008	2	Force and motion
		August 6th, 2008	2	
		August 20th, 2008	2	Magnetic force
		September 3rd, 2008	2	Wave and its properties
		September 17th, 2008	2	Radioactive decay

* This classroom observation was undertaken in a grade 12 physics class instead of a grade 10 physics class.

In the first classroom observation, the teachers each introduced the researcher to their students but not informed them the research purpose. Usually, the researcher sat at the back of the classroom (behind the students) with a video- and audio recorder, and not moved himself to other places of the classroom until the teachers finished their instruction. Despite the fact that the researcher aimed to understand teaching practices of the teachers from their perspectives, he as an outsider was unlikely to leave his perspectives while conducting classroom observations. Therefore, he utilized the etic mode of observations, instead of trying to leave it, by considering the teachers’ content representations, interactions with students, instructional strategies, and student learning assessments through his perspectives, and then shared those with the teachers. During classroom observations, the researcher avoided taking notes in order to not make the teachers feel like being evaluated. However, he collected instructional materials used for reminder and later analysis.

Data Collection in Phase 2

The second phase of the research involved the teachers and the researcher coming together to engage in collaborative action research, which was initiated to promote their learning to improve teaching practices and classroom situations. As previously defined, collaborative action research in this research was considered as discourse where the teachers and the researcher met regularly in order to reflect on particular classroom situation(s), share relevant perspectives, and seek appropriate actions to be taken for the improvement. As being in the discourse as one of its members, the researcher was able to have access data emerged in the discourse and examine how the teachers engaged in and learned from it.

However, it was important to note here that there only were the two beginning teachers (Ms. Jantra and Mr. Sakchai) participating in collaborative action research since the two experienced teachers (Mrs. Darika and Mrs. Rattana) withdrew from the research after the first phase. Mrs. Darika had a health problem, so she had to receive treatment three days a week. Due to a busy schedule, Mrs. Rattana preferred to do action research individually; she got this idea from a “classroom research” conference to which she attended during the first semester (Details of the conference are discussed more in Chapter V). As a consequence, there were overall three participants of collaborative action research (Ms. Jantra, Mr. Sakchai, and the researcher).

The discourse of collaborative action research was conducted throughout the second semester during October 2008 to February 2009. However, there was no a fixed schedule of meeting among the teachers and the researcher because they had difficulties finding an appropriate time that fitted in their crowded schedule; Mr. Sakchai sometimes had to do urgently assigned tasks as well. Therefore, each meeting depended on making arbitrary appointments, which sometimes occurred out of the school time. Despite the fact that the researcher tried to maintain a close liaison with the teachers, there were some meetings to which one of them could not attend. Table 3 outlines all the meetings occurred in the second phase. It should be noted that the meeting occurred in different places such as the school, restaurants, and Mr. Sakchai's residence. Data from the audio-recorder indicated that each meeting took approximately one to two hours.

Table 3 Meetings during engaging in collaborative action research

No.	Date	Participants*			Recorded Duration (hr:min:sec)
		R	J	S	
1	October 17th, 2008 (morning)	✔	✔	✔	2:14:51
2	October 17th, 2008 (afternoon)	✔	✔	✔	1:35:24
3	November 10th, 2008	✔	✔	-	1:23:13
4	November 14th, 2008	✔	✔	✔	1:04:35
5	November 20th, 2008	✔	✔	✔	1:51:56
6	December 8th, 2008	✔	✔	✔	1:17:09
7	December 18th, 2008	✔	✔	✔	1:28:38
8	December 29th, 2008	✔	✔	✔	1:31:27
9	January 12th, 2009	✔	✔	-	0:43:22
10	January 15th, 2009	✔	✔	✔	1:28:35
11	January 19th, 2009	✔	✔	✔	1:05:17
12	January 27th, 2009	✔	✔	✔	1:35:44
13	February 2nd, 2009	✔	✔	✔	1:56:16
14	February 12th, 2009	✔	✔	✔	1:22:00
15	February 16th, 2009	✔	✔	✔	1:17:19
16	February 19th, 2009	✔	✔	✔	2:37:09

* R means the researcher; J means Jantra; and S means Sakchai.

The data collected in the second phase were mainly from the discourse whose content emerged according to the teachers' interests. For example, the teachers and the researcher spent time to explore and negotiate their pedagogical concerns, reflect on classroom situations, prepare lesson plans, discuss about particular physics content, and diagnose student work. It was the fact that content of each meeting varied and interrelated, so it was hard to identify which content was the main focus of the discourse. The audio-recorder was used to record content of the discourse for analysis.

The researcher continued to visit the teachers' classroom in the second semester. Classroom observations were usually undertaken at least once a week, particularly after the discourse, in exception that the teachers asked for postponement. In observing the teachers' classroom, the researcher aimed to follow up whether and how the teachers used insight gained from the discourse in their classroom and to have first-hand experiences of classroom situations in order to facilitate the teachers' reflection as well as share his reflection with them. In the second semester, the researcher was known by the students, while he was also able to remember some of their name, so the students acted more naturally than they did in the first semester. Therefore, the researcher was able to act as a participant observer who sometimes sat in a group of the students working on an assignment and verbal interacted with them. Moreover, he sometimes was a teaching assistant. Table 4 outlines details of classroom observations undertaken in the second semester.

Table 4 Classroom observations undertaken in the second phase

Teachers	Total Number	Classroom Observations		
		Date	**Period**	**Key Content**
Jantra	10	November 20th, 2008	2	Momentum
		December 4th, 2008	2	Collision
		December 18th, 2008	2	Work
		January 14th, 2009	1	Force diagram writing
		January 15th, 2009	2	
		January 21st, 2009	1	
		January 22nd, 2009	2	
		February 12th, 2009	1	Mechanical equilibrium
		February 13th, 2009	2	
		February 19th, 2009	1	

Table 4 (Continued)

Teachers	Total Number	Classroom Observations		
		Date	**Period**	**Key Content**
Sakchai	7	November 18th, 2008	2	Sound production
		November 24th, 2008	0.5*	
		December 2nd, 2008	2	Natural frequency
		January 13th, 2009	2	Light and shadow
		January 27th, 2009	2	Reflection of light
		February 10th, 2009	2	Light ray diagram
		February 17th, 2009	2	Image formation

* This unexpected period was a special time that Sakchai used to repeat the same content (sound production).

At the end of the research (February 2009), the researcher also used individual semi-structured interview to collect data related to the teachers' perceptions about their own learning during engaging in collaborative action research. The interview items are shown in Appendix B.

Data Analysis

According to Lincoln and Guba (1985), data in naturalistic inquiry can be viewed as constructions stemming from the interactions between the researcher and the data sources during he immerses himself in the research setting. In this regard, data analysis is a process of reconstructing those constructions in order to make them more meaningful and explicit for the researcher and others. Differently from the scientific paradigm, naturalistic data analysis is in general an ongoing process conducted hand in hand with data collection. It is an inductive and constructive process that begins with the data, not a prior theory. Moreover, units of data analysis are not predefined for enumeration but derived from meanings of the data as interpreted by the researcher. Lincoln and Guba (1985) described the process of data analysis for naturalistic inquiry as tasks of unitizing, categorizing, filling in patterns, and member checks. This process is also called "the constant comparative method" (Glaser, 1965; Boeije, 2002).

Unitizing is referred to as the first task of naturalistic data analysis, whose aim is to "label (the data) with the most appropriate codes" (Boeije, 2002: 395). In doing so, the researcher sorts all raw data (e.g., transcriptions of interview, discourse, and classroom observation) into a number of incidents or codes, which are the smallest units of information that can still provide the researcher with sufficient meaning of events or actions even in the absence of any other information of a broader understanding. The incidents or codes might range from one sentence to one paragraph. Then, each incident (together with its label of data collection technique, type of respondent, date, time, and site) is in general noted on an index card. These index cards are collected as representations of raw field data for the next task of data analysis (i.e., categorizing).

The main tasks of categorizing is to construct provisional categories in which some index cards apparently related to the same content can be put together, to devise rules of inclusion that describe the properties of each provisional category, and to render these provisional categories internally consistent. In doing so, the researcher reads each index card's contents in order to determine, based on his tacit knowledge, whether or not the contents of those cards "look/feel-alike" (Lincoln and Guba, 1985: 348). If they do, the researcher groups the same or essential similar content cards in same constructed provisional categories. If they do not, however, the cards are placed into a miscellaneous pile of cards for a later categorizing process. When there are sufficient cards in a constructed provisional category, the researcher generates a propositional statement describing the properties of that category and devises the rules of inclusion for its cards. The propositional statement and the rules of inclusion have to characterize all cards contained in the category.

When all the index cards have been categorized, the researcher needs to review the miscellaneous cards again in order to check if they fit the propositional statement and the rules of inclusion for some provisional category. If they do, they can be assigned to that category. If they do not, however, the researcher might need to discard those cards as irrelevant. Nevertheless, it is suggested that the discarded cards should not exceed more than 5 to 7 percent of all cards to ensure that the current set of categories are not deficient. In addition, the researcher needs to review the current set of categories to make sure that those categories do not overlap with or are not subsets of each other. The categories necessarily are internally as homogeneous as possible and externally as heterogeneous as possible. Moreover, any card must not be assigned into more than one category.

The task of filling in patterns means that the researcher might need to pursue subsequent data to order to fill possible incompleteness in the current set of categories. Based on the patterns in the current set of categories, the researcher might feel the absence of some categories or some information and decide the gap needs to be filled, leading to the construction of unknown or absent categories, making connection among current constructed categories, and proposing possible new information to verify the existence of those categories (Guba, 1978: 59 cited by Lincoln and Guba, 1985: 349-350). The process of filling in patterns and revising the categories is continued until the researcher feels the data collection and analysis can stop. Guba (1978 cited by Lincoln and Guba, 1985: 350) suggested four “stop signal” clues, including the exhaustion of sources, saturation of categories, emergence of regularities, and overextension.

The researcher needs to review the entire category set once again to ensure that nothing has been overlooked. Moreover, it is also necessary for the researcher to do member checks of the entire category set with respondents. In other words, the researcher's reconstruction of the set of categories needs to be taken back to the respondents for their examination and reaction. All data analysis processes are necessarily kept track of data manipulation. For instance, raw data, transcriptions of interview, discourse, and classroom observation, index cards representing the incidents, development of provisional categories together with their propositional statement and the rules of inclusion, and the entire set of categories are essentially recorded.

Data analysis in Phase 1

In the first phase of this research, data analysis was done with the aim to categorize key patterns of teaching practices of all the four participant teachers. At the beginning, the researcher transcribed and coded the interview data of each teacher in order to identify his or her conceptions of teaching and conceptions of science. These identified data were then used as a referent for classroom observations. Following the process described above, data from classroom observations were transcribed and coded within the case of each teacher in order to categorize key patterns of his or her teaching practices. Then, cross-case analysis was followed to generate broader categories covering teaching practices of all the teachers. Overlapping among the categories was then done to ensure their internal consistency. However, since the first phase of the research was conducted only in one semester, saturation of the generated categories was not fully guaranteed.

Data analysis in Phase 2

As the second phase of the research involved with how the (two beginning) teachers engaged in and learned from collaborative action research, the researcher "focused on trying to understand (the) teachers' experiences narratively" (Clandinin and Connelly, 2000: 128) using interpretative-analytic considerations rather than employed the constant comparative method to produce a set of discrete categories. The reasons for doing this were that a narrative can represent "a mode of knowing that captures … the richness and the nuances of meanings in human experiences" (Carter, 1993: 6); be capable to "render life experiences, both personal and social, in relevant and meaningful ways" (Connelly and Clandinin, 1990: 10); and invites readers for further analysis and discussion on it (Clandinin and Connelly, 1989). With this regard, the researcher analyzed the data in order to construct a narrative view of experiences shared by the teachers.

In doing so, as guided by Clandinin and Connelly (2000: 127-137), the researcher transcribed conversations in the discourse, classroom observations, and interviews. He then read and reread the transcriptions as well as related documents in order to construct a chronicled or summarized account of what is contained within them. He did "narratively code" (p.131) relevant parts of the transcriptions and the documents in order to develop story lines or narrative threads that interweave and interconnect where, when, and how actions and events occurred with or by whom. The narrative threads, which are based on actual experiences, also included tensions that emerged during collaborative action research both within and across the experiences of the teachers and of the researcher. This is an ongoing, reflective process by which the researcher had made meanings of social experiences shared by the teachers.

However, it is very important to note that this research was not conducted in the fashion of "narrative inquiry" (Clandinin and Connelly, 2000). A narrative was only used for the purpose of presenting the research results as it well fits into a mode of case reporting recommended in "naturalistic inquiry" (Lincoln and Guba, 1985). In this research, a narrative was used to allow the readers to determine credibility of the research as they are able to examine the emergent research process, leading to the research results.

Trustworthiness of the Research

Trustworthiness is referred to as criteria to determine whether or not research results produced by a naturalistic research are worth taking into account (Lincoln and Guba, 1985). To establish the trustworthiness of this present research, the researcher had immersed himself in the research setting for overall eight months in order to observe teaching practices of the teachers and to develop research relationships with them. With this period of time, the researcher was likely to discern both common and salient features about their teaching practices in order for him to address to the first research question. Particularly for the second research question, collaborative action research was not initiated at the beginning of the research but a few months later, the researcher had therefore developed some degree of rapport with the teachers. Since collaborative action research had been maintained for later five months, the researcher with the extended rapport was open to substantial data for examining how the teachers engaged in and learned from it.

The researcher used multiple sources and methods to gather the substantial data such as teacher interviews, classroom observations, group discourse, and a collection of documents (e.g., instructional materials, lesson plans, teacher journals, student work, and the researcher's field journals). These data allowed him to do triangulation in order to test consistency or inconsistency among them. Moreover, the audio- and video-recorder allowed the researcher to reexamine the data in advance as often as possible particularly when he felt that he did miss some relevant events during being in the research setting. Using this technical tool, the researcher was able to enhance his interpretations and be more effective to monitor and adjust the research process and his actions. It was this tool that opened up the researcher to paying more attentions to some particular points that needed to be inquired and checked with the teachers.

The researcher monitored the emergence of the research process and the development of working hypotheses on a regular basis. He recorded changes that occurred during the research process and decisions made in order to adjust the research process according to the changes. Occasionally, the researcher consulted the research committees who debriefed him about the adjustment of the research process, so he was able to check appropriateness of his decisions as well as reasonability of his working hypotheses. Moreover, the researcher recorded how the collected data had been manipulated until the research results were achieved. The track of data manipulation is always available for later reexaminations. Also with support from the research committees, the researcher’s working hypotheses were carefully considered and analyzed in order to be continuously revised to be more consistent with and grounded on the data. All of these processes were conducted throughout the research, not conducted at the end of the research.

As noted earlier in the limitation of the research (see Chapter I), the researcher can not exactly know in a prior way about how the results of the present research might be applicable to other contexts. Therefore, it should be the readers to make determination of whether or not and to what extent the research results can be used in their contexts. On the part of the researcher, he can best provide the readers with a contextual description of the research as well as information about the participant teachers. The readers can use these to consider relevance of the research results to be used for their own sake. In this regard, the researcher decided to use a narrative as the way to convey content and process of the discourse where the teachers and the researcher engaged in and learned from collaborative action research. It was the researcher's expectation that the readers will construct their own meanings of the narrative that will be presented in the following chapter.

CHAPTER IV

TEACHING PRACTICES OF PHYSICS TEACHERS

This chapter addresses the research question—*how do physics teachers conduct teaching practices in their given context?* It focuses on developing an understanding of teaching practices performed by each of the case teachers before they all engage in collaborative action research. By considering teaching practices as a result of an ongoing process by which an individual teacher has made meaning of his or her experiences of involvement in the school of science, each of the case teachers' educational background, conception of science, and conception of teaching, which are personally constructed, are presented accordingly. In each case, these are followed by description of teaching practices. At the end of the chapter, emergent themes across data sets on the case teachers are presented and discussed.

Case of Mrs. Darika

Background

Mrs. Darika spent her elementary education in a big southern province of Thailand, where science teaching was dominated by teachers' story telling and students' note taking due to inadequate laboratory equipment and textbooks. After that, she pursued her secondary education in Bangkok, where physics teaching was dominated by lectures that emphasized numerical physics problem solving. During her school age, she was a high achieving student, normally ranked at the top-three of the class. Becoming a teacher was Mrs. Darika's passionate desire. Indeed, she pursued for associate-degree equivalence in a teacher college (called *Rajabhat*) for two years and chose physics as a major subject. For her to make this decision, studying physics involved applying formulas to numerical physics problems, and did not require a lot of memorization. One year after getting the degree, she passed a teacher qualification test[2] to become a lower secondary science teacher in a public school in a province nearby Bangkok. She then pursued a bachelor's degree in education (physics teaching) in a university in Bangkok as a part time student. During that time, she recalls that she did "not understand physics at all" due to the limitations of time and dominance of lecture. She had taught lower secondary science for 26 years and, during that time, she received an award for an outstanding (third-level) teacher. Since she moved to teach in the present school, she was assigned to teach physics. She expressed that she had inadequate physics content as she had "never touched" it for almost three decades.

Conceptions of Science

Mrs. Darika held two views of science: 1) science is nature and 2) science is a study about nature. These two views were mentioned interchangeably. For example, she said that, "Science is things around us. It is nature that we experience everyday. We can explain things in nature using science" (Second interview, July 29, 2008). Thus, it is not clear whether science for her is a study that explains nature or nature itself. With regard to scientific knowledge acquisition, Mrs. Darika expressed her intuition that, "Scientific knowledge is acquired through observing a thing that happens repeatedly. We observe and experience it many times until we realize, *Hey! This is science*" (Second interview, July 29, 2008). In a more sophisticated sense, she mentioned that scientific knowledge is acquired through doing experiments in order to test a hypothesis. She exemplified how scientists would know whether or not the universe has a boundary as follows:

> We hypothesize that our universe has a boundary. We must have variables. What do we suppose to be the variables? Under what circumstances can the universe have a boundary? Then, we design an experiment to investigate what we hypothesize. (Second interview, July 29, 2008)

[2] During that time, government teacher qualification was not required for a bachelor degree in education.

Mrs. Darika also believed that scientific knowledge can be empirically proven through experiments. Provability of scientific knowledge, for her, distinguishes law and theory.

> Theory is proposed yet not proved. It is a proposition like a hypothesis that no one has disproved yet. Everyone has to accept (unless the theory is disproved). Law is reasonable. It was proved and can be proved (again). So, law is better than theory. (Second interview, July 29, 2008)

In terms of relationships among science, technology and society, Mrs. Darika mentioned one aspect where, "Science relates to technology. Technology must use scientific knowledge … Technology is used for the benefit of human and society" (Second interview, July 29, 2008). Based on these conceptions of science, she expressed a purpose of learning science that was "to understand nature and be able to live with it" (Second interview, July 29, 2008).

Conceptions of Teaching

Mrs. Darika held two dominant conceptions of teaching science as "making students curious in science by telling stories" and "doing experiments to discover science." These two conceptions of teaching science had developed through her school age and teaching experience in the lower secondary level. However, as she perceived students' expectation in the present school, she began to form an alternative conception of teaching as "feeding students content", which was against her previously-developed conceptions of teaching science.

Making students curious in science by telling stories

During elementary times, Mrs. Darika's interest in science was influenced by her teachers' stories. Although the stories alone were sometimes insufficient, it made her curious to know new things about science. Consequently, she had formed a conception of teaching as telling stories aimed at creating students' curiosity and interest in science. Students' curiosity in a story being told increased their verbal participation and this made her very impressed:

> The most impressive experience of teaching science for me was that kids wanted to know. They were curious. They were asking, I mean, always asking. ... I didn't even think they were very curious (about human organism) like that. (First interview, July 8, 2008)

Telling stories about science became Mrs. Darika's normal practice. She had developed various stories related to particular content. She also stated that what is most challenging in teaching science for her was to make students curious in science. She wished to make and see "students' eyes sparking" as they were curious in science. She evaluated whether or not her own teaching was successful by observing students' eyes or facial expressions.

> What is most challenging for me is to make students' eyes sparking. … Each time I teach, I observe them. If I feel that their eyes are sparking, I feel I am successful. But, if I see their eyes are filled with (*Stopped speaking*). They are not responding. I feel discouraged. (First interview, July 8, 2008)

Doing experiment to discover science

Although Mrs. Darika rarely experienced performing experiments during her school age, she did "impress upon students to do experiments" and "want them to discover science through doing experiments" (First interview, July 8, 2008). In doing so, she would ask "why" questions in order to make students think. She then elaborates on what they think in order to guide them to discover science.

> I would ask kids, or do whatever that makes them think. "*Why is it like this? Why is it like that?*" Let them think. Sometimes I let them do an experiment. They could discover a new thing when they are doing the experiment. (First interview, July 8, 2008)

It seemed that the conception of teaching as “doing experiments to discover science” was developed since Mrs. Darika became a lower secondary science teacher. Being a science teacher allowed her to experience doing experiments with students as well as to see “students’ sparking eyes” when they discovered new things from the experiments. She contrasted her own learning experience, in which doing experiments was limited due to the lack of laboratory equipment, with what she wished for her students to experience as follows:

> We learn science well when we are experimenting. ... If I had opportunities to do some experiments (when I was young), I felt that I could understand and I could learn. (First interview, July 8, 2008)

Feeding students content

As Mrs. Darika changed to teaching physics in the higher secondary level, the two conceptions of teaching, which had been previously developed during teaching in lower secondary, were challenged by her experience with the present students. The students, who highly valued marks and were concerned about university admission, expected her to directly tell them what they were supposed to learn in order to pass tests. They denied participation in instructional activities (e.g., playing games) that Mrs. Darika planned to create to arouse their curiosity and interest in content being taught. She described this “hurtful” experience as follows:

> For now, the teacher (*Referring to herself*) only feeds (content). … They (students) told me, “*Teacher, you just teach what you want to teach. … You don't waste time doing this (playing game). It is useless*.” From that time on, I have to change. I mean, “*Look at explanations. Content is like this. Who is confused, do the exercise.*” They just want this (telling content and doing exercise). ... I have to teach in a way that they want. … I feel it works. They like it. (First interview, July 8, 2008)

The students had a goal to pass university admission tests. Thus, they expected their teachers to help them achieve well on the tests. Instructional activities that they perceived as not necessary to achieve that goal were not desirable. Mrs. Darika perceived this expectation as she said, “They just fear that they will fail gaining admission to study in university” (First interview, July 8, 2008). The present school context created a new condition for her to form an alternative conception of teaching, which seemed to be against her previously-developed conceptions of teaching.

Teaching Practices

Data from six two-period grade 10 classroom observation about classical mechanics exposed that Mrs. Darika taught physics in a manner consistent with her initial conceptions of teaching. She told stories about science, aiming to create students' curiosity and increased classroom participation. Also, she allowed students to do experiments. Nevertheless, she placed an instructional emphasis on presenting students with content and solving numerical physics problems. Interestingly, this instructional emphasis was less referred to during the interview but outstandingly appeared in the classroom observation.

Emphasizing numerical physics problem solving

In general, Mrs. Darika informed students the intended content and asked them to look at the content in instructional materials (e.g., information sheets and exercise sheets). She provided students with definitions of physics terms as well as introduced physics formulas before demonstrating with a few examples of how to apply the formulas to numerical physics problem solving. Students copied the examples she wrote on the blackboard. On some occasions, some students were asked to solve physics problems on the blackboard instead of the teacher. Students were then assigned to complete a number of physics problems from the exercise sheets.

Mrs. Darika impressed upon the students to practice numerical physics problem solving, “You have to practice by yourself. Try. When you go back to your dormitory, redo what you noted in the class. You have to do it by yourself" (First classroom observation, July 23, 2008). She seemed to consider numerical physics problem solving as a skill, which students could acquire by practicing, saying, "If you don't practice (on numerical physics problem solving), when will you be skillful" (Third classroom observation, August 11, 2008).

Mrs. Darika mainly assessed student learning using paper-pencil tests, which emphasized numerical physics problem solving. Items on the tests were similar to those in the exercise sheets, but their numerical values were different. Thus, similar procedures used to solve problems in the exercise sheet were applicable to problems in the tests. Nevertheless, students were asked to invent a "science toy" project, which was assessed by Mrs. Darika in terms of how they applied physics concepts in inventing the project.

Telling story and teacher-led discussion

During teaching, Mrs. Darika often told stories or used demonstration to initiate classroom discussion. Compared to when she explained numerical physics problem solving, students participated in classroom discussion more actively as they responded to teacher questions and also posed many questions. However, both telling stories and classroom discussions were led by the teacher, who selected the responses or questions the students posed in the context of the classroom discussion. It was often that stories told were not pertinently related to the content taught and, as a result, classroom discussion lacked focus. Mrs. Darika arbitrarily moved the discussion from one focus to another without providing any connections among them. It seemed that telling stories and teacher-led discussion primarily served as a way to increase classroom participation, but not as a means to promote students' understanding of the physics content that was intended for teaching.

Doing experiment to prove scientific knowledge

Three of six observations in Mrs. Darika's class involved doing experiments. Students did experiments in gender-mixed groups of four to six as a normal arrangement. However, in all three experiments observed, Mrs. Darika told students an exact experimental procedure as well as expected results before allowing them to do it. While the students were doing the experiments, she walked around the room telling them what to do as well as monitoring if they followed the procedure. "Is that true?" was a question often asked. In order to get an experimental result that was the same as what the teacher expected, the students asked the teacher questions to make sure they were following the right procedure. Due to limited time, Mrs. Darika wanted the students to complete experimenting as quickly as possible. Once the students finished the experiment and got data, she told them how to manipulate the data in order to get the "correct" result. In cases where the students got a result different from the expected one, they were asked to repeat the experiment. Noticeably, the students were rarely required to provide their own interpretation and explanation of what they observed from the experiments. This was a contradiction of what she had mentioned in the interview in which she emphasized on students' thinking process, intending to elaborate on what students think to help them discover science. It was apparent that she wanted students to prove scientific knowledge through doing experiments.

Limitation in physics content

Mrs. Darika disclosed that she had a limitation in physics content. Her limited physics content was reflected in her impetus view of force, a partial understanding of friction, and that of mechanical equilibrium. These were clearly apparent when she presented content, told students stories, and held discussions with them. For example, she explained an object's instant velocity at the highest position as it was thrown up in the air and then it would fall back to the ground due to gravity as follows:

> It (object) goes like this (moving up into the air). When its force is gone, it would then fall down. At this (highest) position, it has no force—the force we threw. (First classroom observation, July 23, 2008)

Limitation in physics content influenced Mrs. Darika's teaching practices. She communicated her impetus view of force and the partial understandings to students. She transformed limited physics content into incomplete forms (e.g., normal force is always up and weight is always down). These could create or reinforce students' alternative conceptions. Besides, the impetus view of force seemed to hinder her from capturing the key idea of Newton's third law of motion as well as to limit her ability to recognize students' learning problems, resulting in difficulty in discussing with them. As a consequence, opportunities for conceptual learning were limited in her physics class.

Case of Mrs. Rattana

Personal Background

Mrs. Rattana received her elementary and secondary education in a private school. During that time, she mainly studied science through lectures and doing paper-pencil exercises. She did not achieve high success in studying science and, in particular, she failed two physics courses. Failing physics made her wonder, "Why can't I study this subject?" As a consequence, she decided to study physics at the university level in order to answer her wonderment. Becoming a teacher was not her first intention; however she carelessly and unintentionally selected the faculty of education. After getting a bachelor's degree in education, instead of being a teacher she wished to work for a business company until her father asked her to try a teacher qualification test a few years later. She passed the test and became a government physics teacher in a rural secondary school. While teaching in the school, she had spent summer time for four years pursuing a master's degree in science education with an emphasis on physics teaching. She moved to teach in the present urban school two years ago. With 14 years as a physics teacher, she feels very comfortable with the teaching profession.

Conceptions of Science

Mrs. Rattana considered science as an invisible discipline about surroundings that needs to be studied and understood. By "invisible," she compared science with black magic whose product (i.e., knowledge) is mysterious. Thus, it is necessary to make such knowledge explicit and prove it as true. In opposition to black magic, scientific knowledge for her is empirically provable.

> Science is a discipline that we need to study and know. Actually, it's like black magic. It is invisible (mysterious). We have to make it explicit and prove it to be true (demystify it). (Second interview, July 25, 2008)

In expressing a view of scientific knowledge acquisition, Mrs. Rattana tended to portray knowledge as something that is consumed, saying "Scientific knowledge is acquired through study, searching (for information) and reading books" (Second interview, July 25, 2008). Perceiving knowledge producers, she continued, "They (scientists) also conduct experiments." Conducting experiments, for her, is a method used to prove scientific knowledge. What was proved as true is called "law or regulation," which is unchangeable and must be obeyed. What is proposed yet not proved is called theory, which serves as a "guide or framework" for further scientific studies. Thus, a theory for her can be either changed to be a law when it is proved or ignored when it is disproved.

> Law means regulation. It is unchangeable. But theory is a framework. It's like when people say, "*We study according to this person's theory*." If the next generations show that it (theory) is not true, we can change. ... Law means what we have to follow. Theory is like a guide, leading to law. There must be a theory first. Prove or experiment it. Yes, it (experiment result) obeys this (theory). Then, it can be a law. (Second interview, July 25, 2008)

In terms of relationships between science, technology, and society, Mrs. Rattana expressed an understanding, which is the same as Mrs. Darika's in, "Science and technology are related for sure. Some technologies use scientific knowledge in their production" (Second interview, July 25, 2008). However, she added a moral aspect of science that, "Use of technology in society is like a two-edged sword. Society prospers if it (technology) is used in a good way. It (society) deteriorates if technology is misused." Based on these conceptions of science, purposes of learning science for her were to "know" scientific knowledge and "use" it in everyday life in a good way.

Conceptions of Teaching

Mrs. Rattana held three conceptions of teaching as conveyed in the following quotes: "providing students detailed explanations," "developing good relationship with students," and "using students' language." All three conceptions of teaching evolved since her school age and consolidated as she gained more and more teaching experience. Consequently, she holds these conceptions of teaching very strongly.

Providing students detailed explanations

Mrs. Rattana studied science in school through lectures and doing paper-pencil exercises. As a student she had to intentionally listen to what the teacher said in class, trying to understand, as well as spend more time re-studying it. She thus credited teachers who provided her detailed explanations.

> In our days, I felt the teachers fully … explained in details. They provided different problems and they explained all ways (in which the problems could be solved). Then, we (students) spent remaining time studying by ourselves. (First interview, July 10, 2008)

As a consequence, she remembered the way she was taught and did "imitate" such way of teaching in her class. This is consistent with what Blanton (2003) and

Nashon (2006) observed that quite often science teachers tend to teach the way they were taught. She believed that it was necessary for a teacher "to advise them (students) first, so they could learn." Her role as a teacher was to provide detailed explanations to students.

> I remember that (the way she was taught) to teach kids at the present. I feel that if I don't advise, they (students) wouldn't understand. At least, I must advise them, "*(To solve) the problem like this, you must write this and this*." (First interview, July 10, 2008)

In tracing this conception of teaching, she recalled feedback from her university supervisor when she was a student teacher that, "You (Mrs. Rattana) have to explain to kids. You have to tell them that what variables in the problem relate to what they are supposed to find to get the answer. Tell them first. When they get that, they can do other similar problems" (First interview, July 10, 2008). Also, this conception of teaching was consolidated when she was pursuing her master's degree in which she implemented a computer assistant instruction (CAI) with students.

> There were some students who commented to me that if I let them only see on computer screen, they don't understand. They wanted me to teach first and then use this (CAI) as supplementary. I still remember what they wrote. (First interview, July 10, 2008)

Developing good relationship with students

Mrs. Rattana emphasized an affective aspect in instructional process. In order to teach students, a good relationship between her and them must be established. Based on good rapport, she wished that students would feel free to ask her questions whenever they did not understand.

> First of all, teachers must understand kids. ... We must understand, be intimate, and be informal with them. Kids will come if we are informal ... kidding. Kids dare to tell that, "*I don't understand this.*" (First interview, July 10, 2008)

This affective conception of teaching was formed at least since Mrs. Rattana was in grade 7. During that time, one teacher showed her a way in which a teacher should talk to students. "Beautifully speaking" as well as "calling students children" were recalled as very impressive experiences and this impression is still vivid in her mind. She used this way of talking to establish a good relationship with students.

> I was impressed by one teacher. She beautifully talked to me and always called me "child[3]."... I felt that if I were a teacher, I had to talk beautifully with kids. (At the present,) I always use "child" with kids unless I am angry. ... If we (teachers) use "child" with kids, it seems we are close to them. (First interview, July 10, 2008)

Using students' language

In the context of the study, many students normally use local southern Thai when they talk to each other, but they use formal central Thai when talking to teachers or when discussing in classrooms. Mrs. Rattana recognized the importance of different languages used in the school. She mentioned that she preferred to use students' language, which included students' slang and local southern Thai words. She believed that using students' language could help them understand content better than using formal language as used in textbooks.

> The language I used was very homegrown (locally southern). I speak a language that is close (familiar) to kids. ... If the language we (teachers) mediate to kids is too formal, they do not understand. We must use language like the one they use at home. (First interview, July 10, 2008)

[3] The word 'child' is used in Thai as 'luke,' which represents a relationship between parent and child, not that between a teacher and students.

This conception of teaching was formed at least since Mrs. Rattana became a teacher in a rural school. At that time, students did not understand her explanations. Then, she asked high-achieving students to teach low-achieving students. While she listened to conversations among them, she recognized that the students used a language of their own.

> When I was teaching, kids did not understand the language I used. I asked high-achieving kids to teach low-achieving ones and I listened to them. They talked together and they understood each other. I thought it was interesting. This is what I got from the kids, that I must use kids' language. (First interview, July 10, 2008)

Mrs. Rattana also argued that students in the present school agreed with her way of using such language.

Teaching Practices

Four grade 10 classroom observations about mechanical equilibrium, waves, heat, and nuclear physics, as well as one grade 12 classroom observation about nuclear physics indicated that Mrs. Rattana taught physics in a manner consistent with her conceptions of teaching. She did lectures, providing detailed explanations about numerical physics problem solving to students. Her lectures were often interrupted by students' use of homophones, slang, and local words. Interestingly, despite sitting in groups, none of the students did the hands-on activities or group discussion.

Emphasizing numerical physics problem solving

Mrs. Rattana placed an instructional emphasis on numerical physics problem solving. This emphasis was explicitly shown at the first glance of classroom observation, with posters on walls around the classroom consisting of physics formulas. To commence each teaching period, she generally informed students to look at one of a number of physics problems on an exercise sheet. Then, she explained to students “calculation principles” or a set of steps to be followed in order to apply physics formulas to the problem. Teaching physics content generally went hand in hand with explaining the calculation principles. For example, she explained a calculation principle used to solve problems about mechanical equilibrium as follows:

> Write all forces acting on objects. Then, consider each object separately ... Write forces acting on each object. (First classroom observation, August 7, 2008)

Explaining calculation principles primarily aimed at helping students solve physics problems rather than promoting their conceptual understandings. Physics concepts that underpin the calculation principles were not emphasized. For example, equilibrium conditions (e.g., an object was stationary or moving with a constant velocity) were rarely mentioned when compared to “all left force is equal to all right force.” Moreover, calculation principles were presented in a form hopefully easy for students to memorize, although they were sometimes scientifically poor. For example, in teaching Snell's law of water wave refraction, she told students to memorize that, “Deeper (water) is more speed, more λ, and more θ” because it “could make more people die” (Third classroom observation, August 28, 2008). Students were expected to apply physics formulas effectively and it did not matter whether or not they understood physics concepts.

> You (student) don’t have to know where this formula ($T = 0.693/\lambda$) comes from. … For now, just use it. (Fourth classroom observation, September 4, 2008)

With a few examples of numerical physics problem solving provided, students were asked to “try” solving problems similar to the examples. They were expected to follow calculation principles as well as to “imitate” the examples in order to solve the physics problems. Mrs. Rattana walked around the classroom to monitor if students had difficulties following calculation principles. Some students could not simply follow calculation principles. For example, in studying mechanical equilibrium students had difficulty identifying the normal force as well as the direction of friction. This learning difficulty seemed not be recognized by the teacher. She kept telling students to write all forces acting on the object with no attempts to know why they overlooked some necessary force and/or added unnecessary forces into the problem system.

What criteria was used and how Mrs. Rattana assessed students' learning also reflected the instructional emphasis on numerical physics problem solving. She mainly used paper-pencil tests to assess whether or not they could successfully solve numerical physics problems. As some students did not perform well on tests, she asked them to redo the tests until they got a half of full marks. She asked students to invent a project or write a report related to physics content when they had poor marks.

Accelerating the instructional pace

As Mrs. Rattana's basic physics course was overwhelmed by a variety of physics topics, she accelerated the instructional pace to cover all content in a given time using some strategies. She urged students to study at her expected pace. Also, she compared an amount of content that she had successfully covered in one classroom with that in the other. She used positive reinforcement (e.g., special marks) for students who were able to complete as many physics problems as she expected. Accelerating the instructional pace might relate to a concern about content coverage as Mrs. Rattana expressed to the researcher as follows:

> I will finish (all content) next week. ... I hurry. ... I have to do some kind of time management this year. I eliminate some content. … There is a good deal content (to be taught). (Personal conversation, September 4, 2008)

Mrs. Rattana also asked students for additional periods, taking students' leisure time for teaching. In doing this, she had to snatch students' leisure with other teachers who could not complete their content as well.

Teacher-dominated discussion under an evaluative culture

Taking a role as explainer, Mrs. Rattana dominated classroom discussion, which mostly consisted of her explanations and closed-ended questions about numerical physics problem solving. Students made little contribution responding to the teacher's questions with short answers. It was often that Mrs. Rattana answered her own questions. By comparing students' participation with and without the presence of the researcher, Mrs. Rattana reasoned for students' limited participation as follows:

> They (students) feel risky. On Monday (without presence of the researcher), they dared to express ideas. But, if there is someone else (*Referring to the researcher*), they wouldn't. I used to tell them, "*Come on, and please answer*. *What do you fear?*" (Students stated that) "*No, teacher. I may answer wrongly*." (Personal conversation, August 14, 2008)

What Mrs. Rattana reasoned could be considered as the Hawthorne Effect, in which students' behaviors including classroom participation could be influenced by the presence of the researcher. It was possible that students responded less to the teacher's questions than normal. However, in looking at the preceding quote, it might also be the case that students hesitated to answer Mrs. Rattana's questions because they did not want their answers to be evaluated as "wrong."

Mrs. Rattana generally evaluated students' answers in a right-or-wrong manner. In other words, there were some expected answers that she wanted students to say. Students' contributions of expected answers continued instruction in a smooth manner, which Mrs. Rattana presented more information extending from the expected answers. However, when unexpected answers or even silence were contributed, she seemed to be unsatisfied. Negative signals (e.g., sighing, long utterance, and nodding off or scratching head) were sent to students. As she mentioned in the class, she believed that she must get angry in order to make students answer.

What caused students' lack of participation in the classroom could also be a contradiction of rules created by Mrs. Rattana. For example, on the one hand she told students to be free employing whatever methods for solving a physics problem they wanted while, on the other hand, she specified or strongly recommended only one method. Once students employed a method different from the recommended one, Mrs. Rattana sent the negative signals representing dissatisfaction. Also, she told students to use standard international units while, in exception of some topics, she preferred using prefix and suffix. This contradiction of rules as well as negative reactions to unexpected answers could decrease students' participation.

In addition to the right-or-wrong evaluation as well as the contradiction of rules, Mrs. Rattana created a classroom culture in which those who did not know or incorrectly knew some content would or must be shy. Students seemed to instill this culture. When some student provided a wrong answer, laughing and ridiculing about that answer occurred. Under an evaluative culture, students developed a variety of strategies to survive from blaming, laughing, or ridiculing by others. The most common strategy was looking at documents and reciting what the teacher wanted them to say. Or, answering only one short word before providing a longer one allowed students to check whether a positive or negative reaction that the teacher from the teacher would occur. When directly called to answer a question, some students denied answering by asking the teacher for a pass to the washroom or negotiated to answer the question as a group.

Mrs. Rattana rarely tried to understand what students thought and why they thought in that way, particularly when they provided unexpected answers. Therefore, it was not unreasonable noting that besides the presence of the researcher, the ways in which she reacted to students' answers could result in lessened students' participation.

Using gags to motivate students

Mrs. Rattana normally used gags during teaching. She played on words that students said using Thai homophones. Also, she invented classroom slang as well as used local southern words. When she used this special language, students participated in classroom discussion more actively as they used their own gags. Thus, this kind of language serves as a means to kidding students, developing rapports with them, and increasing their motivation rather than a way to promote an understanding of physics content. She explained physics content using formal language. On some occasions, Mrs. Rattana's special language could be "linguistic noise" as some students did not understand the meanings of such language. It sometimes interrupted students' learning.

Case of Ms. Jantra

Personal Background

Ms. Jantra spent elementary and lower secondary education in private schools, and higher secondary education in a public school. She indicated her own achievement in science as "moderate." She enjoyed learning science during elementary grades as she had studied "new things like stars." However, teaching physics in her secondary classes was dominated by lecture and doing paper-pencil exercise with no experiments. The lack of opportunities to do experiments made problems for her when studying in a faculty of science in which she was required to learn physics more authentically. As a PSMT student, she spent four years for a bachelor's degree in science (physics major) and one more year for a diploma in science teaching. While pursuing the diploma, she had experienced student teaching in a secondary school for one semester. Nevertheless, becoming a teacher was not her initial plan. She applied for the PSMT in order to "try on the test" before the university entrance examination. She decided to study in the PSMT after passing the test because she was not sure whether or not she would succeed on the highly-competitive university entrance examination. She began her teaching profession in the present school and has taught there for one and a half years.

Conceptions of Science

Ms. Jantra had difficulties expressing what she meant by science. At first, she expressed that "science is things around us" without clarification of what those things are. As examples were provided, she agreed that science is a human perspective used to explain things and/or phenomena.

Researcher: According to your understanding, what is science?
Ms. Jantra: Science is things around us.
Researcher: Could you clarify that?
Ms. Jantra: Natural phenomena are also science. ... It's like raining. We can use science to explain how it occurs. ... It depends on how we see them (things or phenomena). It's like a natural resource or the environment. We can see it as an ecological system. It's a perspective.
Researcher: Can I say science is a perspective on things or phenomena around us?
Ms. Jantra: Yes.
(Second interview, August 5, 2008)

Ms. Jantra believed that scientific knowledge is acquired through forming hypothesis-testing experiments. An experiment can be set to empirically test a hypothesis whether or not it is true. She exemplified that, "People say that heat can make metal extend. We experiment and prove whether or not what they say is true" (Second interview, August 5, 2008). Besides, observations, searching for related information can be used to generate a mathematical model of non-experimental phenomena such as astronomy. A mathematical model needs to be proved, to see whether their prediction is true. She also believed in objectivity of scientific knowledge.

> If they (two scientists) investigate the same thing and have the same data, results they get are the same. (Second interview, August 5, 2008)

For Ms. Jantra, scientific knowledge must be provable through doing experiment. She distinguished law and theory by considering a level of acceptance by scientists. Although she was not sure which one of them gained a higher level of acceptance than the other, she believed that one of them would become the other since it was proved as true.

> I can not remember whether law or theory occurs first. I am not sure whether law or theory is accepted first and then it becomes the other. It was accepted by many scientists as true. (Second interview, August 5, 2008)

Like the previous two teachers, Ms. Jantra mentioned one relationship among science, technology, and society, saying, “Science, technology, and society are related because scientific knowledge is required to produce technology. Then, technology is used in society” (Second interview, August 5, 2008). Based on these conceptions of science, purposes of learning science for her was to “explain” natural phenomena using scientific knowledge as it is accepted by scientists and “use” such knowledge in everyday life.

Conceptions of Teaching

As a novice teacher, Ms. Jantra took both a role of teacher and that of student interchangeably when talking about teaching. She automatically matched learning physics with numerical physics problem solving. As a consequence, she held two conceptions of teaching as “helping students to think and solve numerical physics problems by themselves” and “assigning students to practice numerical physics problem solving.” These two conceptions of teaching were shaped by her learning experience in school. Besides, though not strongly, she tended to hold a conception of teaching as “doing experiments and group working” since she experienced a new learning activity in the university.

Helping students to think and solve numerical physics problems by themselves

In opposition to biology, Ms. Jantra perceived physics as a subject that did "not require a lot of reading," but calculating. Throughout three years in higher secondary grades, she had studied physics through lecture with an emphasis on solving numerical physics problems. She described her experience learning physics by comparing and contrasting the teaching practices of two physics teachers (called Teacher A and Teacher B) as follows:

> Teacher A went very quickly. He skipped steps—not beginning with analyzing problems. ... Teacher B had his own steps—explaining (content), analyzing problems (by asking) what variables are provided (and) what formula to be used. Both did lecture. (First interview, July 14, 2008)

In order to understand physics, Ms. Jantra had to pay attention to what the teachers said. For her, knowledge mostly occurred in class. It thus was difficult to successfully solve physics problems, if she could not catch up with what the teachers said.

> We (as students) must intend to study. ... When a teacher is teaching, we study and listen to what the teacher says. Knowledge mostly occurs in class. If we understand in class, we can search for other problems to do more. But if we don't understand in class, we will get struck. (First interview, July 14, 2008)

It was also important for Ms. Jantra to search for additional numerical physics problems for practicing. Success in determining correct answers made her enjoy studying physics. She tended to automatically match studying physics with numerical physics problem solving.

> I liked physics, its content, ways of thinking (and) solving problems. After a teacher taught, I searched for other problems beyond what the teacher taught.

> It was enjoyable, if I could find answers. And, I could continue (to solve problems). (First interview, July 14, 2008)

As Ms. Jantra had only studied physics through solving numerical physics problems, she formed a conception of teaching as “helping students to think and solve physics problems by themselves.” Based on her experience of different teaching practices from the two physics teachers, she recognized her role as a physics teacher to guide student thinking about physics problems using questions. She expected students to think and be able to solve physics problems by themselves.

> In solving physics problems, I want them (students) be able to analyze and solve problems by themselves. We (teachers) shouldn’t tell kids what information a problem provides. Let them think by asking or guiding them ... I want to teach and help kids be able to solve problems by themselves. (First interview, July 14, 2008)

Assigning students to practice on numerical physics problems solving

According to Ms. Jantra, “(learning) physics is a skill. It needs a lot of problems ... doing a lot of problems until having the skill” (First interview, July 14, 2008). Thus, it was her responsibility as a teacher to assign students to solve a number of numerical physics problems in order to acquire such skill. By conceptualizing learning physics as a skill, she assumed students’ difficulty in solving physics problems due to the lack of such skill. To help them learn physics, she would assign students to do more exercises in order to develop or acquire the skill.

> Suppose kids cannot solve problems ... cannot analyze the problems. We (teachers) can use exercises that allow kids to do a lot of problems until they have the skill and learn. (First interview, July 14, 2008)

Ms. Jantra simply assumed that the more students practiced on numerical physics problem solving, the more students could learn physics. This conception of teaching might have been formed since her lower secondary education in which she studied science through doing a lot of paper-pencil exercise.

> Teaching science was about lecturing by teachers. The teachers demonstrated procedures on the blackboard. Then, they gave us exercise ... a lot of exercise (about) 20-30 items a day. (First interview, July 14, 2008)

Doing experiment and group working

Although Ms. Jantra had never experienced doing experiments during her school age, she had some in the university. Doing experiments provided her new experience in learning physics. She described this new experience as follows:

> I liked studying science when I got opportunities to do experiments. I liked doing experiments because we (as students) did it as a group. We didn’t know whether or not a given theory was true. When we were doing an experiment and got it (experiment result) consistent with the given theory—it was true as people had said, this helped us better understand (the theory). (First interview, July 14, 2008)

Although Ms. Jantra did the experiment in order to “prove” a theory, she developed a positive attitude to learning science. She realized that doing experiments and working in a group were important for learning science. Consequently, this experience influenced her to form a conception of teaching, which emphasized on doing experiments and group work. Nevertheless, it was very infantile when compared with the previous two conceptions of teaching.

Teaching Practices

Seven observations of Ms. Jantra’s grade 11 physics class about energy (e.g., heat and wave) indicated that she placed an instructional emphasis on numerical physics problem solving. Her teaching practice fell into a cyclic pattern comprised of presenting well-defined physics terms, introducing physics formulas, and demonstrating examples of numerical physics problem solving. While teaching, she verbally interacted with students in an initiate-respond-evaluate (IRE) manner. On some occasions, she allowed students to work in groups to solve physics problems. She sometimes assigned students to search for information of specified topics and study the information themselves. That is, she taught in a manner consistent to her conceptions of teaching.

Emphasizing numerical physics problem solving

Ms. Jantra's teaching practice heavily relied on a cyclic pattern in which she commenced with presenting students definitions of physics terms, followed by introducing physics formulas, and demonstrating examples of applying those formulas to numerical physics problems respectively. She came to the class with a few pieces of paper on which definitions of physics terms, physics formulas, and physics problems were noted. Then, she wrote such information onto the blackboard, allowing students to make a copy in their notebook.

During presentation of information, Ms. Jantra often stopped speaking immediately and continued with the writing of what she was supposed to talk about. Also, she frequently asked students questions about definitions of physics terms and students recited what was on the blackboard or in documents. Students sometimes were not familiar with physics terms (e.g., loop) as they asked the teacher to clarify. Little clarification was provided. Moreover, Ms. Jantra's content presentation sometimes was scientifically incomplete. For example, she explained momentum of a moving gas molecule as it exists after the molecule hits a container's wall as follows:

> When a gas moves and hits a wall, there would be momentum happening. What is the momentum formula? (Third classroom observation, August 26, 2008)

Ms. Jantra’s content presentation directly and quickly aimed at physics formulas. Then, she devoted most of her teaching time for demonstrating to students how to apply physics formulas to numerical physics problems. In doing so, she called each student's name and asked a series of questions related to solving a physics problem until its answer was addressed. After providing a few examples, Ms. Jantra assigned students to do numerical physics problem solving, normally as a group.

Ms. Jantra’s assessment regime also reflected the instructional emphasis on numerical physics problem solving. She mainly used paper-pencil tests comprised of questions to recall physics contents as well as numerical physics problems. In addition to cases that students did not perform well on the tests, which frequently occurred, she assigned students to search for a number of numerical physics problems and wrote those physics problems together with the methods used to determine their answers. She accounted for a number of numerical physics problems written in the report rather than what students learned. The criterion was that students had to write ten problems to get one point.

Initiate-respond-evaluate (IRE) classroom discussion

Ms. Jantra generally controlled classroom discussion using a series of questions about well-defined physics terms and numerical physics problem solving. In doing so, she called students to stand up and answer the questions. As a result, classroom discussion was continued in an IRE manner in which Ms. Jantra initiated asking a question followed by a student’ short response. And if the response was evaluated as correct, she moved to the next round of the IRE cycle. Otherwise, if the response was incorrect, the same question was asked again.

It was often that Ms. Jantra did not pay attention to students' answers, although they were responding to her own questions. She asked a question and then turned back to writing things on the blackboard—ignoring student’s answers—and then turned back to the student asking her or him to answer again. She expressed a purpose of asking questions and calling students’ name to respond the questions as follows:

> They (students) would not get sleepy. If I don’t call on them, just doing (solving physics problem) on my own, they would not listen to me. When I call on them, they must be alert. (Personal conversation, August 5, 2008)

Students were familiar with Ms. Jantra’s IRE cycle as they knew what kind of questions and when she would ask. It became a funny game for some of the students to propose their friend's name in order to attract the whole class’s attention to their friend.

Group working on assignments

Ms. Jantra often asked students to do assignments in a group or pair. The assignments varied such as summarizing content in a textbook, studying an information sheet, completing an exercise sheet, and practicing on numerical physics problem solving. Exercise sheets generally were full of recitation of physics terms and numerical physics problems. While doing an exercise sheet, students opened a textbook/notebook page by page—looking for some information to be filled in on the exercise sheet or for calculation examples similar to problems in the exercise sheet to be followed. Assigning students in groups to search for specified contents as well as examples of numerical physics problems was generally used when Ms. Jantra missed some periods, when she could not complete the amount of content as she expected, or when students did not perform well on tests.

Case of Mr. Sakchai

Personal Background

Mr. Sakchai spent his elementary and secondary education in rural public schools. He indicated his own achievement in science as “not so good.” However, his achievement gradually improved and this made him feel more confident to learn science. During that time, he mainly studied science through lecture with a few opportunities to do experiments. Rather than physics, Mr. Sakchai preferred mathematics and planed to be a mathematics teacher. Unfortunately, his marks on the university entrance examination did not allow his first choice. He majored in physics instead because "it is about calculation like mathematics." He spent four years in teacher preparation including one semester for student teaching experience. After getting a bachelor's degree, he began his teaching profession in the same school as Mrs. Rattana and had taught there for one year. Then, he moved to teach in the present school, (same as Ms. Jantra) as a non-government teacher due to the lack of science teachers in the school. He was waiting for a teacher qualification test to become a government teacher.

Conceptions of Science

Mr. Sakchai viewed science as "a study of all natural phenomena," which serves scientists' wonder. Scientists, for him, are ones who investigate natural phenomena whose data is originally disorganized. They then summarize that data into a more systematic format.

> A scientist wants to know whatever about nature. Data (about what to be studied) at first is disorganized and no one summarizes it systematically. Once he wants to know this, he then investigates (and) summarizes into law or theory or the like. (Second interview, July 30, 2008)

Mr. Sakchai believed that the "scientific process had its own steps," which can be divided into two main phases: collecting data and summarizing data. Although he could not recall all of the steps and had difficulty providing an example, he stated that, "there must be investigating, searching, experimenting, summarizing ... something like that." Scientists have to follow such steps exactly in order to acquire scientific knowledge, which is objective.

> If they (two scientists) do the experiment differently—one goes directly (*Referring to following the steps exactly*) while the other one makes mistakes,

> they could get different results. But if they go the same way, finally their results would be the same. (Second interview, July 14, 2008)

Due to a belief in objectivity of scientific knowledge, Mr. Sakchai argued that everyone can show and prove scientific knowledge as being true. This could be done through an experiment. The belief in objectivity as well as the understanding of the scientific process as data summarization influenced a way in which he distinguished law and theory. He considered theory as a framework to investigate natural phenomena. Once theories used to investigate the same phenomenon were consistently proved as true—pointing to the same result, they can be summarized into a law, which can not be confuted. For him, law is a product of a theory-summarizing process.

> Theories are summarized into a law. Law can not be confuted. It's true for sure. ... Scientists investigate using a number of theories. Once they see the theories are true, they (scientists) then summarize into a law. (Second interview, July 14, 2008)

In terms of relationships among science, technology, and society, Mr. Sakchai expressed one relationship like the other three teachers that, "We use scientific knowledge in producing technology to be used in society for convenience" (Second interview, July 14, 2008). Based on these conceptions of science, learning science for him was a way that helps organize one's thought and thinking to be more systematic as they are at first disorganized.

Conceptions of Teaching

Similarly to Ms. Jantra, Mr. Sakchai as a novice teacher took both a role of teacher and that of student when talking about teaching. On the one hand, he mentioned what students should do to understand physics while, on the other hand, he stated what he could do as a teacher to help students learn. Consequently, he held two conceptions of teaching as "repeating readings and practicing on numerical physics problem solving" and "doing experiments that allows students to explicitly see experimental results." These two conceptions of teaching were formed since his school age.

Repeated readings and practicing on numerical physics problem solving

Mr. Sakchai had mainly studied science through lecture. Thus, it was important for him to intentionally listen to what a teacher said in class in order to understand content being taught. However, only listening to the teacher was not enough. It was necessary to re-study content at home.

> The first thing (to understand physics content) was to intentionally listen to a teacher. After that, when I arrived home, I had to review (the content). (First interview, July 9, 2008)

Mr. Sakchai argued that reading a book only one time might not be enough for him. In order to understand physics content, he might need to repeat readings many times.

> I liked repeating (and) practicing. When I did not understand the first reading, I still read and read. ... When I didn't understand at the first round (of reading), there should be a second, a third, and so on. It must be until I understood. (First interview, July 9, 2008)

Repeating readings was a learning style, which Mr. Sakchai felt most appropriate as he mentioned, "For me, it must be repeating." He reasoned that once he knew how to learn through repeated readings, his achievement in science gradually improved. The improving achievement made him feel more confident to learn science as well as convinced him to believe in such a learning style.

> I didn't know the style. I just studied and studied (aimlessly). When teachers lectured, I didn't understand (and) I didn't like it. Once I knew the style—how to study science. I felt I like it. (First interview, July 9, 2008)

Besides repeated readings, Mr. Sakchai mentioned that practicing on numerical physics problem solving was necessary. He said, "In studying physics, I must do a lot practicing ... Practice on a lot of problems. Only book reading was not enough" (First interview, July 9, 2008). This experience in studying physics had formed a conception of teaching which emphasized repeated readings and practicing on numerical physics problem solving. In addition, he wished students to find their own learning style.

> I want kids to practice thinking (*Referring to numerical physics problem solving*) by themselves. Teachers should not tell them everything—just advising. Let them think by themselves ... to find answers using their own ways. (First interview, July 9, 2008)

As Mr. Sakchai expected students to repeat readings and practice on numerical physics problems, he often blamed students' lack of responsibility when they had difficulty studying physics.

Doing an experiment that allows students to explicitly see experiment results

Doing an experiment and getting a result similar to what was described in a textbook was an impressive learning experience for Mr. Sakchai. He expressed that this kind of experience made him proud of himself as well as better understanding physics content.

> When a teacher let us (students) do an experiment, we experimented and got a result. The result was as same as the teacher's ... as same as its real value. I

> was impressed. I felt so proud. … What I learned though doing experiments, I remember ... I still keep it in mind. (First interview, July 9, 2008)

Thus, Mr. Sakchai wanted students to do experiments—allowing them to explicitly and really see what is described in a textbook. He expected that, “When they (students) really experiment, they could remember (and) better understand” (First interview, July 9, 2008). In doing so, students needed to follow an experimental procedure in order to get and see a result similar to or consistent with scientific knowledge. After that, it was his role to provide scientific explanations of the experiment.

> They (students) were following (procedure). Then, they got what I expected. It (experiment) was about using ripple tanks. They were able to do the experiment and saw a clear (wave shadow) image. They didn’t understand (how the image occurred). They asked how it occurred. I had to explain until they understood. (First interview, July 9, 2008)

Teaching Practices

Five observations of Mr. Sakchai’s grade 10 basic physics class, which was studying a variety of physics content (e.g., motion and force, magnetism, waves, and nuclear physics), indicated that he taught in a manner consistent with his conceptions of teaching. He spent most of the teaching time for numerical physics problem solving. He generally summarized content into items or cases aiming at helping students effectively solve numerical physics problems. He used a variety of illustrations to explicitly show students natural phenomena as well as convince them to believe in the content being taught. As he intended to provide explanations both about the natural phenomena and about numerical physics problem solving, the classroom was occupied by his monologues.

Emphasizing numerical physics problem solving

In each period, Mr. Sakchai presented physics content such as definitions of terms and examples of natural phenomena before introducing physics formulas and demonstrating how to apply the formulas to numerical physics problems respectively. In doing so, he generally organized physics content or formulas into a number of cases with regard to problem situations. For example, he classified a friction formula ($f = \mu N$) into two cases: a horizontal plane and an incline plane, although both situations required the same understandings. According to different values of N—the normal force that a plane acts on an object—to be substituted into the formula, he presented two formulas for the two situations—$f = \mu(mg)$ for a horizontal plane and $f = \mu(mg\cos\theta)$ for the incline plane. He aimed at helping students apply each formula to problem situations appropriately.

Besides, he suggested students to notice "key words" described in problem statements in order to solve physics problems. For example, students had to notice whether a problem statement indicated "rough" or "slippery" surface in order to consider whether friction should be taken into account in solving the problem. However, his suggestion was sometimes too simplistic and also logically problematic—being effective for numerical physics problem solving only.

> If the problem doesn't tell an angle, it means that the object moves on the horizontal plane. Whenever there is an angle appearing in the problem (statement), use the incline formula. (Second classroom observation, August 6, 2008)

After presenting physics formulas and "tactics" for problem solving, Mr. Sakchai demonstrated examples of how to apply the physics formulas and tactics to numerical physics problems. In particular, solving physics problems which appeared in the past university entrance examinations were asked for students' special attention. Through seeing and imitating his procedural approach, it was time for students to solve similar problems—practicing!

> I will show you some examples. I will leave problems requiring the same procedure for you. Do these by yourself. (Fifth classroom observation, September 17, 2008)

The instructional emphasis on numerical physics problem solving was clearly apparent when the semester was running close to the end. Mr. Sakchai accelerated a pace of instruction in order to cover an amount of given content. In addition, he decided to ignore non-calculation descriptive content and assigned students to read such content by themselves.

> You have to read (a textbook). All content here is descriptive. It's just common content. There is nothing about calculation. (Fifth classroom observation, September 17, 2008)

Mr. Sakchai's assessment regime also emphasized paper-pencil tests about numerical physics problem solving. There was a small space for "common content" in the final examination. He also assessed students' exercises and notebooks for special marks, particularly when they did not perform well on the tests.

Using a variety of instructional media to illustrate natural phenomena

In addition to content presentation, despite inadequacy of laboratory equipment in the school Mr. Sakchai provided opportunities for students to see natural phenomena related to content being taught. He used a variety of instructional media such as equipment available in the school, computer animation, figure, and even stationery. According to him (Personal conversation, July 30, 2008), "They (students) should have a chance at least to see things authentically." Such media were used to convince students to believe in content being taught. For example, he asked students to put a rubber on a ruler and then incline one side of the ruler seeing whether or not the rubber would swerve down along the ruler. Then, he convinced them that "there is friction."

All illustrations were conducted in a show-and-tell manner, which students were asked to see what Mr. Sakchai wanted them to see before he told them its scientific explanation. For example, he made a longitudinal wave through a spring showing and convincing students that there were compressions before explaining that the spring particles vibrated parallel to the direction of wave propagation. “Do you see that?” was commonly asked when he illustrated natural phenomena to students. He sometimes asked them to see rippling water on the blackboard. Nevertheless, students were rarely asked to observe and explain the natural phenomena as shown in their own ways.

Question-like monologues

As Mr. Sakchai intended to show natural phenomena in order to provide scientific explanations as well as explained numerical physics problem solving, he was the one who mostly spoke in the classroom. Although there were a lot of question-like sentences in his talks, he immediately answered his own questions without providing wait time for students to think and respond. According to a conversation with him (Personal conversation, August 27, 2008), he was not aware of this kind of speaking. He concentrated on content coverage with a fast instructional pace and forgot to provide students wait time.

Limitation in physics content

Similarly to Mrs. Darika, Mr. Sakchai had limitations in physics content, which was apparent when he explained natural phenomena to students. Most clearly, he believed that medium particles would move in the same way as a wave propagates through. In other words, he believed that, “A wave is sent from the source” (Third classroom observation, August 20, 2008).

> (A wave propagates from) deep water to shallow water. This is the direction of water flow. … Some water reflects back (to deep water) while some can pass into the shallow area. (Third classroom observation, August 20, 2008)

Besides, Mr. Sakchai had limitations in classical mechanics because of the language difference between physics and everyday life. For example, while teaching Newton's third law of motion he told students that action and reaction occur simultaneously while, a moment later, the prefix "re" mislead him to state that reaction occurs after action. Similarly, he explained to students that, "Inertia means a kind of motion where an object slowly moves in a straight line with a constant velocity" (First classroom observation, July 30, 2008). The term "inertia," which in everyday language means "passive" or "slow" resulted in an incomplete explanation. Of course, Mr. Sakchai communicated these to students.

Cross-Case Analysis

This section describes a cross-case analysis of the four case teachers' teaching practices and a discussion on factors that have shaped them.

The teachers employed content-driven instruction that emphasized numerical physics problem solving.

Teaching practices of the four physics teachers were consistent with the content structure of their respective schools' curricula. In order to cover the prescribed content throughout the semester, Mrs. Darika and Mrs. Rattana prepared instructional materials such as information sheets and exercise sheets and went back and forth along the sheets. Ms. Jantra and Mr. Sakchai whose school had limited use of materials, prepared notes on intended content and delivered the content to students through writing on the blackboard and/or telling. All the teachers informed students what the content to be taught was at the beginning of each period and delivered their instruction by covering content they had prepared. They rarely took students' interest into consideration and rarely adjusted the instruction according to them.

Due to the large amount of content to be covered, the teachers encountered difficulty covering all content in a given time. This difficulty was clearly apparent in the case of Mrs. Rattana and Mr. Sakchai who taught grade 10 basic physics. By "basic physics," the two teachers argued that students both in the science and non-science streams had to study all content prescribed in the National Science Curriculum Standards (IPST, 2002) as a compulsory subject within one semester. According to them, the purpose of this course was to make students familiar with physics terms. Consequently, the content was superficially taught in a "touch and go" manner as they accelerated the pace of instruction in order to cover all the content.

How much content should be taught in a given time has been an issue of "depth versus breadth" in reforming science education (Anderson 1995; Wright, 2000; Schwartz *et al*., 2009). Results of this study indicated that the teachers tended to take the "breath over depth" stance. This claim supported the pilot study (Ladachart and Roadrangka, 2008) suggesting that physics teachers in the province employed content coverage instruction. Nevertheless, Newmann (1988) cautioned that covering breadth of content without promoting depth of understanding might be a waste of time.

In addition to content coverage, the teachers emphasized numerical physics problem solving. They quickly presented and sometimes ignored descriptive content, such as scientific explanations of natural phenomena, before driving the instruction toward physics formulas. They spent most of their teaching time explaining and demonstrating to students how to solve numerical physics problems. Based on examples provided, students then were asked to "imitate" and "practice" solving similar physics problems. Instead of thinking about how natural phenomena occurred, students were encouraged to think only about how to solve numerical physics problems successfully.

The instructional emphasis on numerical physics problem solving could relate to the national assessment regime (Changbin, 1995). In Thailand, the external summative tests (e.g., O-NET, A-NET, GAT, and PAT) are used as gatekeepers or selection tools of higher secondary students to university (Coll, Dahsah, and Faikhamta, 2010). As high-stakes testing, these university admission tests inevitably put pressure on both students and teachers (Pringle and Martin, 2005). As a consequence, the pressure could influence the teachers to focus only on what would be in the tests as well as develop students' test-taking skills (Wideen *et al*., 1997). This was clearly demonstrated by Mrs. Rattana and Mr. Sakchai. Also, Mrs. Darika was adjusting her teaching practices to meet students' expectation by focusing more on numerical physics problem solving. Thus, the national assessment regime hinders, and also narrows down, the intentions of the education reform (Dahsah and Coll, 2008).

The teachers compromised their personal conceptions of teaching with influences from contextual factors.

All four physics teachers held different conceptions of teaching and they attempted to achieve such conceptions in teaching physics. Mrs. Darika preferred telling stories when she considered them relevant to content being taught. Also, she often provided students with the opportunity to do experiments. On the other hand, Mrs. Rattana employed a lecture approach with some gags to develop a good relationship with students. And, Ms. Jantra asked a series of questions about numerical physics problems in order to guide students to think more carefully and systematically about the problems. Mr. Sakchai used a variety of instructional media in order to explicitly show students natural phenomena. This consistency between conceptions of teaching and teaching practices supported Koballa *et al*. (2005) who claimed that conceptions of teaching held by teachers can be used as referents to understand their teaching practices.

Nevertheless, the context in which the teachers taught also influenced their teaching practices. As previously noted, the national assessment regime highly influenced the teachers to emphasize numerical physics problem solving. Also, school context was influential to the extent which the teachers could achieve their conceptions of teaching. For example, under a supportive school context, Mrs. Darika could easily achieve her conception of teaching—doing experiments. This seemed more difficult for Ms. Jantra and Mr. Sakchai, who also valued doing experiments but had inadequately equipped laboratories. As a consequence, they abandoned hands-on activities. This was the opposite of Mrs. Rattana, who rarely mentioned doing experiments. Although her school had adequate laboratory equipment, she never provided students with the opportunity to do hands-on activities. Nevertheless, the school context seemed to have less influence compared to conceptions of teaching held by the teachers. This finding is consistent with Gess-Newsome *et al*.'s (2003) argument that conceptions of teaching (or personal practical theories) most powerfully influence teachers' teaching practices.

Compared to conceptions of teaching and contextual factors, the education reform policies (ONEC, 1999; IPST, 2002) seemed to have less influence on teaching practices of the teachers. They did not refer to the education reform when talking about teaching physics. Although they expressed some agreement with the student-centered approach, when directly asked, they argued that it was not applicable to some students including those who were low-achieving, less responsive, and not interested in science. This supported Coll *et al*. (2010: 19) who has noted that, "Many teachers (in Thailand as well as other developing countries) report paying lip service to 'learner-centered' education" (see also, Dahsah and Faikhamta, 2008).

The teachers' teaching practices influenced classroom discourse where student idea contributions were limited.

The teachers' teaching practices influenced classroom discourse. In general, they controlled what was taught as well as how much time was spent on each topic. Thus, as previously noted, classroom discourse was mostly occupied by numerical physics problem solving. Nevertheless, differences of classroom discourses as influenced by each teacher were noticeable. Mrs. Darika's stories made students curious about content being taught so they asked questions as well as expressed ideas, resulting in a teacher-led discussion. Under an evaluative culture, Mrs. Rattana's explanations dominated classroom discourse while students hesitated to express ideas unless the teacher used gags. Ms. Jantra's recitation questions shaped classroom discourse in an IRE manner. Mr. Sakchai's question-like sentences without wait time did not allow students to construct long sentence answers. That is, students' opportunities to make contributions to classroom discourse varied depending on ways in which the teachers verbally interacted with them.

The nature of questioning also varied from one teacher to another. They mostly asked close-ended and recitation questions, which required recalling basic information of content being taught (e.g., definition of terms and formulas). Responding to such questions, most students simply guessed the answers or recited what was described in instructional materials instead of expressing their own understanding. Thus, students' prior understandings remained untouched. Chin, Brown, and Bruce (2002) suggested that such questions generated little productive discussion.

Besides the nature of questioning, how the teachers reacted to students' responses to their questions is important. Whether explicitly or implicitly, they tended to evaluate students' answers, which were mostly short, in a right-or-wrong manner and they preferred the right ones. They reacted to such answers in order to drive the instruction forward. Oppositely, wrong answers, which sometimes implied alternative conceptions, were often ignored or sometimes reacted to negatively. There were few, if any, attempts to clarify the wrong answers. Hammer (1995b) suggested that being overly concerned about the correctness of students' answers creates a difficulty in generating a productive classroom discussion.

In order to generate a productive discussion, a teacher should allow students to express their ideas with the aim of helping them articulate their own conceptions (van Zee and Minstrell, 1997a). The teacher has to allow him/her-self wait time for thinking and trying to understand what they think (Dawes, 2004). As students' thinking may not be clearly stated, it is necessary for the teacher to tolerate flaws and ambiguities of their statements, help them clarify the statements, and respond to the statements in a neutral and respectful manner (Hammer, 1995b; van Zee *et al.*, 2001). Besides, classroom discussion should be conducted in familiar contexts in which students have made observations of what is being discussed for a period of time (van Zee *et al.*, 2001). The teacher sometimes has to allow the instructional plan to be diverted during classroom discussion (Hammer, 1995b). These characteristics were rarely demonstrated by the teachers in this study.

The teachers employed behaviorist instructional strategies instead of constructivist ones.

The teachers tended to employ behaviorist instructional strategies. For them, learning physics was considered a skill, which students could acquire through repeatedly practicing numerical physics problem solving. As a consequence, they directly presented well-defined physics terms and formulas, demonstrated how to solve numerical physics problems, and encouraged students to imitate and practice solving similar numerical physics problems. In doing so, they aimed to form a connection between stimuli (physics formulas and numerical physics problems) and students' responses (problem solving procedure) through repeating or even trial and error. Positive and negative reinforcements were considered normal to strengthen such a connection. They gave special marks for students who contributed right answers and completed an exercise while they sometimes sent negative reactions (e.g., signing and scratching of the head) for wrong answers. Punishment and deducting marks were also often used as a warning to intimidate students' regarding their undesirable behaviors (e.g., chatting and not listening to the teachers). These well reflected a behaviorist view of learning (National Research Council [NRC], 2000).

According to Duit and Treagust (1998), behaviorism was the dominant learning theory in education during the first half of the 1990s before the emergence of constructivism, which now underpins Thailand's educational reform. Nevertheless, the behaviorist view of learning is still available in educational systems (Farnham-Diggory, 1994). Results of this study supported Pillay's claim (2002) that many Thai teachers held the old-fashion learning theory as they heavily relied upon behaviorism—emphasizing a connection between a stimuli and a response (SR), as well as the use of reinforcement. Furthermore, Pillay (2002) continued that support provided to them (e.g., materials) is also outdated and needs serious revision.

Yager (1991) suggested that the behaviorist view of learning, though useful, is not enough to prepare students in the present time and he also proposed the constructivist view of learning. According to Duit and Treagust (1998), the main ideas in the constructivist view of learning are that knowledge of the outside world is viewed as human construction and learning—a process of acquiring such knowledge—is not viewed as transferring of the knowledge from one who knows to ones who do not know, but that an individual actively constructs the knowledge based on what he or she already knows (prior knowledge) through interacting with the world. In addition, the process of knowledge construction is embedded in a particular setting in which the individual and language are viewed as a heuristic tools that the individual uses to share and negotiate constructed knowledge of his/her surroundings with that of others (Driver *et al*., 1994).

Therefore, in promoting knowledge construction in the science classroom, a teacher has to design activities that allow students to physically interact with a natural phenomenon, elicit and challenge their prior knowledge about it, and encourage them to reorganize or modify such prior knowledge in a manner more consistent with scientific knowledge (NRC, 2000). Thus, learning can be seen as a process of conceptual change (Duit and Treagust, 1998). Discourse among students and the teacher becomes a central aspect in a constructivist science classroom as they share and negotiate various knowledge and understandings about the phenomenon (Driver *et al*., 1994). These conditions were rarely demonstrated by the teachers in this study, which was consistent with the Dahsah and Faikhamta (2008) claim that the constructivist view of learning is new for Thai science teachers.

The teachers had limited understanding of physics content and the nature of science.

All the four physics teachers had a limitation in physics knowledge as it was apparent in their teaching practices. Obviously, Mrs. Darika held an impetus view of force as well as partial understandings of friction and mechanical equilibrium. She often communicated these to students. Moreover, with limited physics knowledge, she encountered difficulty leading classroom discussions towards target concepts of the content being taught. Also, Mr. Sakchai's limitation in physics knowledge was obviously apparent when he provided scientific explanations of natural phenomena to students on many topics (waves, Newton's third law of motion, inertia, and friction). These made his explanations incomplete.

Compared to Mrs. Darika and Mr. Sakchai, the limitation in physics content knowledge was less apparent in Mrs. Rattana and Ms. Jantra. Arguably, both Mrs. Rattana and Ms. Jantra heavily relied upon numerical physics problem solving and rarely explained or discussed with the students how natural phenomena occurred. Nevertheless, it was evident that Mrs. Rattana had difficulty making a distinction between heat and temperature. Also, Ms. Jantra seemed to be confused with diffraction and refraction of waves when both phenomena occurred at the same time. Thus, it was possible that both teachers concealed their limitations in physics content by focusing on numerical physics problem solving (Lee, 1995).

Limitation in content knowledge is not uncommon among Thai science teachers in different grades and subjects (Pongsophon and Roadrangka, 2004; Soparat, Roadrangka, and Tunhikorn, 2007; Sreethunyoo and Yutakom, 2007; Jantaraprasert *et al*., 2008; Kijkuakul, Yutakom, and Roadrangka, 2008; Bongkotphet, Roadrangka, and Panacharoensaward, 2009; Magrood-In, Yutakom, and Jantrarotai, 2009). Buaraphan, Singh, and Roadrangka (2006) claimed that many teachers had mainly studied physics through a lecture-based approach that emphasized numerical physics problem solving and that they were limited in learning physics in a conceptual manner. As a consequence, their alternative conceptions of physics concepts remained unchallenged. When considering the educational background of the teachers in this study, the claim was strongly supported.

In addition to the limitation in physics knowledge, all four teachers exhibited their conceptions of science, which were somehow close to "the myths of science" described by McComas (2000) such as:

- Hypotheses become theories that in turn become laws.
- Scientific laws and other such ideas are absolute.
- A general and universal scientific method exists.
- Evidence accumulated carefully will result in sure knowledge.
- Science and its methods provide absolute proof.
- Scientists are particularly objective.
- Experiments are the principal route to scientific knowledge.
- Scientific conclusions are reviewed for accuracy.
- Acceptance of new scientific knowledge is straightforward.
- Science models represent reality.

Philosophically, the teachers[4] tended to share a realist account, where science aims to "produce knowledge of an extrasensory world (p.163)" that "uncover(s) the hidden nature of reality (p.164)" (Matthews, 1994). They believed that scientific knowledge, as hidden in natural phenomena, is discovered by scientists through experimentation and that a scientist's imagination and inference are not involve in such a process. The teachers thus considered the validity of scientific knowledge (e.g., law and theory) with regard to how accurately it can uncover nature's mechanism.

Results of this study are consistent with those of other studies (Promkatkeaw *et al.*, 2007; Yutakom and Chaiso, 2007; Chamrat and Yutakom, 2008; Buaraphan and Sung-Ong, 2009), claiming that science teachers in Thailand have limited understanding of the nature of science. McComas (2000) explained that this limitation resulted from the lack of the philosophy of science in teacher education programs, the failure of such programs to provide real science research experiences for teachers, and the shallow treatment of the nature of science in textbooks. When considering the case teachers' educational backgrounds as well as the new-coming nature of science in the National Science Curriculum Standards (IPST, 2002), the explanations seem sensible.

[4] In addition to a realist account, only Ms. Jantra may also hold an instrumentalist account when she described science as a human perspective on nature. This may not be surprising since she completed a bachelor's degree from a faculty of science.

Even though literature is still in debate on whether or not and, if so, to what extent science teachers' understanding of the nature of science influences their teaching practices (Brickhouse, 1990; Gallagher, 1991; Lederman, 1992; Mellado, 1997), some consistency between them was realized in this study. Most basically, all the case teachers presented scientific constructs (e.g., force, moment, and heat) in a realistic sense that they really exist. Particularly in the case of Mrs. Darika—the most experienced teacher who taught in the most supportive school, she tended to teach in a manner consistent with her understanding that scientific knowledge is acquired through doing experiments. However, such consistency is rarely apparent in the case of the three younger teachers. Other educational concerns (e.g., classroom management, school context, and instructional emphasis) might hinder them to teach in a manner that reflects their understanding of the nature of science (Lederman, 1999). There is no claim about relationships between the teachers' understanding of science and their teaching practices made in this study.

Summary and Discussion

This chapter has described the teaching practices of four physics teachers based on interpretation of their background, conceptions of science, and conceptions of teaching. It is evident that their teaching practices were content-driven and emphasized numerical physics problem solving, aiming to master students' test-taking skills for future education. With this stance, it is usual that the teachers focused only on physics content (e.g., definitions, formulas, and procedural approaches) and ignored students' alternative ideas associated with content being taught. As a consequence, they were very influential in classroom discourse. In addition, they favored behaviorist strategies (e.g., reinforcement and punishment) to control student learning and behavior in expected ways. This traditional way of physics teaching can be better understood when the following analysis is considered.

Considering each of the case teachers individually, consistency between teaching practices and conceptions of teaching was easily observed. This could be assumed in an optimistic sense that each teacher attempted at best to achieve what he or she considered as “good” science teaching in a given context. However, instead of educational theories of learning or education reform documents, what the teachers considered as “good” science teaching is strongly influenced by their personal experience as students in science classrooms. That is, they referred to impressive events of what their former science teachers had done as exemplars, which were intentionally imitated or adapted in their present classrooms. This strongly supports what Blanton (2003) and Nashon (2006) observed that quite often science teachers tend to teach the ways they had been taught.

To understand this phenomenon, Lortie (1975: 61-81) explained the process of self-socialization by which students had observed the teaching practice of their teachers while studying. It is what he called “the apprenticeship of observation.” They learned about teaching from a student-orientated perspective like “an audience viewing a play” without appreciating instructional intentions and decisions made by their teachers. As a consequence, the students had gradually developed conceptions of teaching based on what they were personally impressed with in the teaching practices of their teachers. Thus, such self-developed conceptions of teaching tended to emphasize affective aspects (Weinstein, 1989). In a sense, this process could be a beginning of situated learning through “legitimate peripheral participation” (Lave and Wenger, 1991) in science classrooms.

Since the process of self-socialization during school age had normally taken many years, personal conceptions of teaching were robust and not be changed easily even though they might be challenged during teacher education courses (Zeichner and Tabachnick, 1981). Once those students became practicing teachers, “what constituted good teaching then constitutes good teaching now” (Lortie, 1975: 65-66) and acts as referents for them to teach in similar manners (i.e., traditional instruction). This is based on an assumption that their students will appreciate and be impressed by their teaching as they (as student) had been before. Consequently, teaching “is more a matter of imitation” (Lortie, 1975: 63) than being based on educational theories of learning or education reform documents.

Along with self-developed conceptions of teaching, a similar mechanism can occur in the development of conceptions of science. As noted by Lederman (1992), "one's understanding of the nature of science is not a simple matter of being exposed to accurate readings or instruction" (p. 344) but is mostly influenced by "instructional behaviors, activities, and decisions implemented (by teachers) within the context of a lesson" (p. 351) particularly on a regular basis. Since the case teachers had studied physics (and science in general) through traditional instruction (i.e., presenting content and mastering numerical problem solving), which the nature of science was rarely made explicit, it is likely that this traditional way of teaching had unconsciously but persistently produced some "distorted" conceptions of science.

Gordon (1984) illustrated possibilities of "hidden curriculum" that can result in a distorted or "bucket" image of science. For example, a well-structured order of science content being covered implies the nature of scientific knowledge as a string of facts to be accumulated; the right answer required by a particular problem/question implies the objective nature of scientific knowledge; and verification of scientific knowledge through experiments implies its status as being out there instead of what is constructed. Thus, during years of involvement in traditional instruction without an emphasis on the nature of science, it is likely that redundancy of these implicit messages that orient to a distorted image of science (e.g., realist account) can be conveyed from teachers to students through ordinary classroom language (Zeidler and Lederman, 1989).

Given this analysis as sensible, it is interesting to remind that the case teachers were implementing traditional instruction through which they had studied science in their present classrooms as a result of the process of occupational socialization. Therefore, it may not be too pessimistic to assume that their present students were developing or absorbing conceptions of teaching as well as those of science similar to theirs through the same mechanism (i.e., apprenticeship). Also, it may not be too pessimistic to imagine and concern that some of those students will become science teachers in next following years after completing a teacher education program and, consequently, will favor implementing traditional instruction in their future science classrooms. As a consequence, traditional instruction will be retained in education systems. Volkmann, Abell, and Zgagacz (2005: 867) called this phenomenon as “the cycle of teacher-centered didactic science instruction.”

However, it is not fair to place all the criticism on teachers since the circumstances in which they teach also supports retention of the traditional instruction. McRobbie and Tobin (1995: 383) once raised a critical question of “why traditional practices continue to be supported” even though they are directly challenged by reform efforts. Consequently, they indicated four “cultural myths,” which include transmitting knowledge, being efficient, maintaining curriculum rigor, and preparing students for examinations, which maintain traditional instruction among science teachers in countries (Tobin and McRobbie, 1996). Also in this study, the cultural myths were exhibited within teaching practices of the case teachers who often lectured students (i.e., transmitting knowledge), concerned with content coverage rather than student understandings of content (i.e., maintaining curriculum rigor and being efficient), and preparing students for tests.

These cultural myths (perhaps among other contextual factors) play an important role interacting dialectically with conceptions of teaching held by individual teachers in order for them to make behaviors viable in a particular context, including student reaction (McRobbie and Tobin, 1995; Tobin and McRobbie, 1996). If contradiction between personal conceptions of teaching and cultural beliefs is perceived, the teachers need to either comply or reconcile both of them (e.g., Zeichner and Tabachnick, 1981; Brickhouse and Bodner, 1992). Or, they may resist compliance and affect changes in the status quo (e.g., Abell and Roth, 1994). However, the latter seems to be unusual, occurring in particular conditions such as a confident, enthusiast teacher working in a context open for new practice. Through this dialectic interaction, once the teachers achieved in making viable behaviors in their context, “a referential system” (McRobbie and Tobin, 1995) of teaching practices exists unless they will experience “cognitive disequilibrium” (Briscoe, 1993) between both of them again.

In this study, it is mostly clear that Mrs. Rattana tended to have a strong referential system of teaching practices since she, with a long history of teaching physics, eased articulating her personal conceptions of teaching viable in her teaching context. This is a bit different from Mrs. Darika who returned to teaching physics five years ago and tended to experience cognitive disequilibrium since some of her personal conceptions of teaching was incompatible in her new teaching context, resulting in formation of a new conception of teaching (feeding content). In the case of the two novice teachers, it is likely that they were in processes of articulating their conceptions of teaching and compromising them with teaching contexts in order to develop a referential system of teaching practices.

In order to change traditional instruction, therefore, Tobin and McRobbie (1996) urged science teachers to reflect on the dialectic relationship between their personal conceptions of teaching and perceived contextual constraints. In a similar vein, Briscoe (1993: 984) suggested that:

> … those who seek to assist in that change must not only provide opportunities for teachers to make explicit and reflect on their personal referent beliefs, but provide experiences that assist teachers in the reconciliation and reconstruction process.

Given the fact that conceptions of teaching associated with traditional instruction held by the case teachers began to be formed during their school age, thus, it is necessary to initiate them to engage in the process of reconstructing their referential system of teaching practices in light of the education reform policy. In doing so, collaborative action research is used as a context and opportunities for them to reflect on such dialectic relationship and reconcile reformed-based recommendations into their teaching practices. The next chapter describes that process by which the teachers and the researcher were involved in collaborative action research.

CHAPTER V

COLLABORATIVE ACTION RESEARCH

Introduction

This chapter addresses the second research question—*how do physics teachers engage in collaborative action research and learn to improve their teaching practices in response to the education reform?* It is important to remember at the beginning of the chapter that the two experienced teachers (Mrs. Darika and Mrs. Rattana) withdrew from the study after the first semester. As a consequence, there were only two beginning teachers (Ms. Jantra and Mr. Sakchai) participating in the collaborative action research with the researcher—a beginning action research facilitator. Therefore, results of the second research question were derived overall from the three participants engaging in collaborative action research.

As noted in Chapter III, the results of the second research question are presented in a narrative form in order to provide the readers with details of a developmental process of the collaborative action research since it was initiated. In the narrative, the readers can trace the involvement of the researcher's actions and intentions during the study, so they are allowed to determine his influence on the teachers' engagement and learning, and vice versa, in collaborative action research. Nevertheless, as analyzed using the constant comparative method, the results can also be presented in a set of categories. To ensure what the researcher intends to communicate, four categories of the results are presented as follows:

1. The teachers engaged in collaborative action research with a number of concerns; however self-concerns were less likely to be made explicit.
2. The teachers tended to accept a reform-based instructional idea introduced by the researcher, but they denied it later when they perceived that the idea did not meet their concerns.

3. The teachers engaged in collaborative action research in order to fulfill needs or alleviate their concerns, leading them to learn to improve their teaching practices.

4. The teachers' learning as a result of engagement in collaborative action research has the potential to create change in their teaching practices.

As presented in a narrative form, the chapter begins with a description of a process by which the three participants initiated in collaborative action research through discussing and negotiating their shared interests. Once collaborative action research was established with a focus on particular pedagogical aspects, Ms. Jantra's and Mr. Sakchai's engagement and their subsequent learning while participating in collaborative action research are then highlighted. After that, the researcher's reflections on his experiences of being an action research facilitator as well as on reforming science education through teacher development in the context of the study are discussed.

Initiating Collaborative Action Research

The teachers' prior agenda to participate in collaborative action research

> Students are not interested in my teaching. They are chatting and playing ... sometimes (girls are) making up their faces. I used to reprimand them but they didn't feel any remorse. … I want to know whether the problem is me, the students, or both. (Jantra, First interview, 14 July 2008)

The excerpt above is what Jantra expressed at the beginning of the study. It is quite clear that she came to participate in the study with a specific agenda associated with students' classroom conduct. At that moment, she was wondering why many of her students did not pay attention to her teaching. Despite the fact that she tried to use instructional strategies (e.g., jigsaw, demonstration, and student presentation) to increase their classroom participation, she did not feel those strategies worked well in her physics class. As noted in Chapter IV, Jantra's physics class, in which she called on each student to answer her questions, consequently fell in the initiate-respond-evaluate (IRE) pattern.

In contrast, Sakchai came to participate in the study with no specific agenda. Knowing about the study without any details from Jantra, he considered it as an opportunity to try “whatever” different from his normal teaching routine. In opposition to the case of Jantra, the researcher initially did not perceive any hints indicating that Sakchai was dissatisfied or concerning with his teaching situation. He described a reason to participate in the study to the researcher as follows:

> So long as no one initiates, I’m still passive. When one comes and encourages me to do research, it would be good for sure. … We can do whatever that will increase students’ achievement. It depends on you. I will get what you give. (Sakchai, First interview, 9 July 2008)

What Sakchai described above supports a caution in action research literature (Goldston and Shroyer, 2000; Ponte, 2002; Sahasewiyon, 2004) that some teachers, when deciding to engage in an action research project, may take a passive role, expecting a facilitator to be their initiator. Ponte *et al*. (2004: 581) reasoned that teachers felt “safer and less confrontational” to do something “thought out by others.” Hence, to help Sakchai find out the beginning of his action research, video records of his teaching were regularly sent to him for self-evaluation throughout the first semester. He was asked to consider some aspect(s) of his own teaching with a view on improving it. Jantra was also asked to do the same task.

Exploring the teachers’ pedagogical concerns and research interests

After finishing student achievement reports for the first semester, Jantra and Sakchai began to explore their pedagogical concerns with the researcher. During a discussion, they expressed a number of concerns, which can be summarized as insufficiency of laboratory equipment, heavy teaching load, inadequate time for content coverage, and students’ small amount of participation, misbehaviors, and low achievement. Consistently, both teachers were most concerned with students' low achievement. Despite this shared concern, the ways in which Jantra and Sakchai each figured out and would cope with it were quite different, depending on their conceptions of teaching.

Jantra contended that students' poor ability in mathematics resulted in their low achievement in physics. According to her, limitation in mathematical skills hindered students in understanding physics content as well as solve numerical physics problems. A consequence was that they lost interest in her physics teaching. Therefore, she proposed to improve students' mathematical ability using an additional exercise that would provide them an opportunity to do more practice with mathematics. It was her belief that it would be easier for students to follow her physics teaching after their mathematics obstacle was overcome. The effect of the exercise on students' mathematics ability, and consequently their achievement in physics, would be assessed using a pre- and post-test under an experimental design.

Despite an agreement that students' poor ability in mathematics could result in their low achievement in physics, Sakchai perceived the imbalance between content and time as the main cause. He argued that teaching periods were used up by school activities (e.g., sport/music competitions, farewell parties, field trips, and speeches by invited speakers), and these activities drove him to inevitably accelerate instruction. Thus, he proposed to develop an instructional media available to students whenever they could not follow his teaching. To do so, he would conduct an experiment and teach (in a show-and-tell manner), record the teaching, and burn it into CDs for distribution. For Sakchai, this could not only overcome the content coverage problem, but also relieve another problem that students were limited to do hands-on activities due to insufficiency of laboratory equipment. Similarly to Jantra, he would use a pre- and post-test to assess the effectiveness of the media on student achievement.

What Jantra and Sakchai proposed are somewhat consistent with Ponte *et al.*'s (2004) study that teachers, when initially engaging in action research, tend to focus on methods, techniques, and strategies that they plan to achieve a particular objective, but "not gear themselves to gaining insight into their current practice and the actual situation (p.580)." Also similarly to teachers in another Thai context, Jantra and Sakchai began to solve the perceived problem "straight away without … reflecting about their action" (Sahasewiyon, 2004: 501). Moreover, it tended to be "actions of others" (Ponte, 2002: 410) instead of their own that they aimed to change.

Jantra's and Sakchai's experimental research stance might be not surprising when considering their prior experience about research. During practicum, they each used to engage in experimental research, implementing a treatment between a pre- and post-assessment of one dependent variable. More recently, during the first semester, the school district held a one-day "classroom research" conference[5] in which they and the researcher were invited to attend. In the conference, the lecturer from a local university spent his morning time describing a number of experimental research designs, validity and reliability before providing suggestions about "how to write" a research report to his audience in afternoon.

Facing up a dilemma: The researcher's point of view regarding the teachers' research interest

Jantra's and Sakchai's propositions to do experimental research created a dilemma in the researcher's mind. On the one hand, it was his role to help them to "get to where they want to get" (Kosmidou and Usher, 1991: 28), while on the other hand, he realized that undertaking such an experimental research might not create a productive learning opportunity for their professional growth and instructional change. Feldman (1994: 99) supports the latter as follows:

> … if the research that teachers are asked to do remains within the paradigm for traditional educational research, there is strong possibility that the teacher-researcher movement will not have a lasting effect on professional practice.

[5] Mrs. Darika and Mrs. Rattana also attended this conference.

Furthermore, the researcher was also concerned that Jantra’s and Sakchai’s research intention might be based on just one part of the classroom situation. From his point of view, they tended to underestimate the perceived problem—students’ low achievement.

Challenging the teachers’ research proposals and prompting the teachers’ reflection

After listening to the teachers, the researcher eventually decided to challenge their research proposals, asking Sakchai whether or not he knew students’ learning problems resulted in their low achievement and how he knew that the media could solve such problems effectively. Similarly in the case of Jantra, the researcher challenged her idea, “Are you saying that you’re going to ask students who normally do not do homework to do more additional exercise?” (Researcher, First group discussion, October 17, 2008)

Jantra and Sakchai shortly responded to the questions with silence. After a moment, the discussion was immediately turned to another point because the researcher felt, in his mind, that he was making the teachers lose confidence of their research proposals. It seemed to be “a culture of niceness” (Nelson, 2009: 566) in which all three participants, including the researcher, hesitated to question or challenge ideas of the others that dealt with the discussion.

The researcher then decided to encourage Jantra and Sakchai to consider their teaching practice in light of how it influenced their students. To do so, they were asked to check whether their teaching practice is as they feel it should be and express how they felt, whether positively or negatively, with students’ reaction to their teaching practice. Subsequently, Jantra began to reflect on her instructional action, “It is like I’m talking with myself … talking with the blackboard.” In an attempt to elaborate this instance of reflection, the researcher then pointed to the IRE pattern in Jantra’s class, and asked her to think of how and why the class fell in such a pattern. Taking a few moments, she realized that, “I emphasized definitions (and) asked only the definitions." In a similar vein, Sakchai reflected on his question-like monologues as follows:

> I hurried and did not place importance on them (students). When I asked a question and they delayed to respond, I didn't wait. *"Answer if you can. If not, I'll continue."* I just checked if they were listening to me. (Sakchai, First group discussion, October 17, 2008)

Proposing an instructional idea derived from the teachers' reflection

As an attempt to shape Jantra's and Sakchai's reflection, the researcher continued to ask, "What do (they) really want when asking students a question?" Then, both teachers answered consistently that they wanted to gain classroom participation from students. Since a shared concern with students' lack of participation became more apparent, the researcher highlighted the teachers' way of questioning as "a living contradiction" (Whitehead, 2000) in which they expected to gain student participation by asking questions, but surprisingly, their way of questioning denied it. Consequently, the researcher introduced an instructional idea that changing the way of questioning and carefully listening to students may lead to a lively discussion on the content being taught—that is, the teachers can gain more classroom participation from students.

Facing up other dilemmas: The teachers' point of view regarding the researcher's idea

However, the researcher's idea in turn created dilemmas for Jantra and Sakchai. They raised a number of pedagogical issues related to the idea, which included: (a) where and how to get "good" questions and how they can come to know that those questions are good; (b) whether a good question really works to gain student participation and whether a classroom discussion takes a long period of time; (c) what they should do when students neither think about nor answer the question, or even when disruptively responding with unrelated answers; and (d) how a lively discussion, if it exists, links to numerical physics problem solving and whether it finally increases students' achievement.

Besides the pedagogical questions, Jantra and Sakchai raised other ones about research. Looking from a position of traditional educational research, they were concerned with whether and how changing questions and at the same time carefully listening to students in order to create a lively discussion can become research activities. In other words, when implementing the researcher's idea, they were concerned about what the research data is (if not a numerical form), how to collect and analyze it, what a measurable outcome is, and whether or not a research conclusion is creditable for other people. Such questions about research are somewhat similar to ones noted by Feldman (1994).

Compromising between the teachers and the researcher

The pedagogical questions raised by Jantra and Sakchai made the researcher frustrated in playing his role as facilitator because it was challenging to provide them with the right answers as was apparent from their questions. Perhaps, in the researcher's thinking, they could best answer those questions by themselves through a process of "monitoring and adjusting of good practice" (Feldman, 1994) while engaging in collaborative action research. As a consequence, the researcher tried to compromise Jantra's and Sakchai's positions with his own, proposing that:

> Before developing an instructional media, it would be better if we know exactly what makes students not understand physics. … Perhaps, poor math ability may not be the only issue. (Researcher, Second group discussion, October 17, 2008)

Explicitly, the compromise urged Jantra and Sakchai to identify students' learning problems in order for them to develop a treatment effectively. Implicitly, it was the researcher's expectation that they would take into account cues of alternative conceptions often emerging through students' short responses during the first semester. For the researcher, to realize students' alternative conceptions, at least in part, it is to better understand the educational situation in which the teachers are involved in—that is, a purpose of engaging in action research (Feldman. 1994).

In dealing with the questions about research, the researcher realized that "action research defies easy description" (McCutcheon and Jung, 1990: 144). It is placed on philosophical assumptions radically different from traditional educational research (McNiff and Whitehead, 2002), in which the teachers of this study believed. According to Ponte (2002: 420), "teachers come to see the purpose of action research by doing it, and they start to do it when they start to understand its purpose." Therefore, an understanding of the purpose of action research might not occur easily in a few discussions unless Jantra and Sakchai began to engage in action research activities.

The researcher thus decided not to tell them any description of action research. Instead, he introduced Feldman's (1996) three mechanisms—anecdote telling, trying out ideas, and systematic inquiry—as ways to engage in a collaborative action research. Simply put, what the researcher meant was that changing the way of questioning and carefully listening to students was the first thing for Jantra and Sakchai to try. While trying, they were asked to monitor influence(s) of their changed practice on student classroom participation. After that, "We will then talk about (reflect on) what happened" (Researcher, Second group discussion, October 17, 2008). Jantra and Sakchai seemingly accepted the researcher's compromise even though many of their questions were left unanswered.

Planning for action: A challenge by the teachers

Once all three participants were successful, to some extent, in compromising a shared focus of collaborative action research, the next task was planning the creation of a lively classroom discussion—that is, generating a "good" question. At that moment, Jantra and Sakchai did not exactly know which subjects and grades they would teach in the upcoming semester. Nevertheless, they were encouraged to generate a question by themselves, find it from available sources (e.g., internet), or ask students what they wanted to know as soon as they knew the content to be taught. The researcher also introduced strategies to create and sustain a lively and productive discussion with students based on suggestions in literature (Lemke, 1990; Hammer, 1995b; van Zee and Minstrell, 1997a, 1997b; van Zee, 2000; Dawes, 2004).

The second semester began soon after a three week vacation. In this new semester, Jantra was assigned to teach a grade 10 physics course continued from the previous one about force and motion. In her present course, students (hereafter called 4/1 students) had to study momentum, work and power, and mechanical equilibrium. Sakchai was switched to teach a grade 11 physics course, which students (hereafter called 5/1 students) had to study sound, light, and geometrical optics. His course was continued after the 5/1 students had studied heat and waves in Jantra's course during the previous semester. Only Sakchai, as a member of the school's academic department, had participated in making decisions about constructing the teaching schedule of each teacher. Jantra knew the subjects to be taught one week before the school was open.

The researcher followed up the questions that Jantra and Sakchai each planned to ask their students. Unfortunately, Jantra said that it was hard for her to generate an open-ended question about momentum, and she had nothing. Potentially, Sakchai did ask his 5/1 students what they wanted to know about sound. However, he argued that the questions they raised were "not pertinent." He provided an example, "Can we hear sound in water?" Oppositely to Sakchai, the researcher thought this question had the potential to engage the 5/1 students in a discussion about sound propagation in different mediums. While the researcher tried to justify the potential of this question, Sakchai challenged the researcher to demonstrate through an example action in his class instead of a speech out of the class. Jantra concurred.

Once challenged by Sakchai, the researcher at that moment felt that he had been pulled from the back to the front of the classroom. Feeling hesitant initially, however he accepted this challenge after considering the pros and cons. The main reasons were that he wished the teachers to discern their students' ability in thinking and engaging in a discussion when prompted to do so through different ways of questioning (van Zee and Minstrell, 1997b). Moreover, an opportunity to observe teaching of another could potentially make them begin to consider change in their practice (Tobin, Tippins, and Hook, 1994). In the worst sense, however, the teachers might probably lose faith in the researcher if the students did not actively engage in a discussion. Based on this reasoning, it was worth trying.

Trying out the idea by the researcher

In Sakchai's 5/1 class, the researcher raised a question about sound production, which was considered the most basic concept of the topic, as follows:

> Imagine that there will be a new student to study in this class soon. Unfortunately, that student has been deaf since he was born. It means he has never heard sound. It is lucky, in an unfortunate way however, that he is literate in reading and writing. As you all are studying about sound, how would you help him know that there is sound occurring outside his world? (Researcher, Teaching in Sakchai's class, November 18, 2008)

The 5/1 students felt hesitant to express their ideas at the beginning. However, with encouragement, some of them felt more comfortable to walk in front of the class and propose ideas. The classroom discussion simply began with an idea of developing a computer animation with a written explanation for the deaf student to see and read. The discussion gradually proceeded to some of the students' attempting to explain how sound occurs. According to them, sound occurs from an impact between two things—either an object and an object, or an object and air, or air and air—that makes vibration resulting in sound. However, what the 5/1 class were struggling with was whether or not such impact was necessary. Taking one and a quarter hours approximately, the teaching period ended with a boy's question, arguing that when tearing a piece of paper, which makes sound, there is no impact.

In Jantra's 4/1 class, the researcher simplified the 21st item in the study of Singh and Rosengrant (2003: 616) to initiate a discussion. The question was selected because it relates to momentum about which the 4/1 students were studying, and it could potentially probe their conceptions of force and motion. The question was:

> As shown in (Figure 2,) rain starts falling vertically down at a constant rate into a cart with frictionless wheels which is horizontally moving at a constant velocity on a slippery surface. How would the cart's velocity be affected when rain water is gradually accumulating more and more in the cart? (Researcher, Teaching in Jantra's class, November 20, 2008)

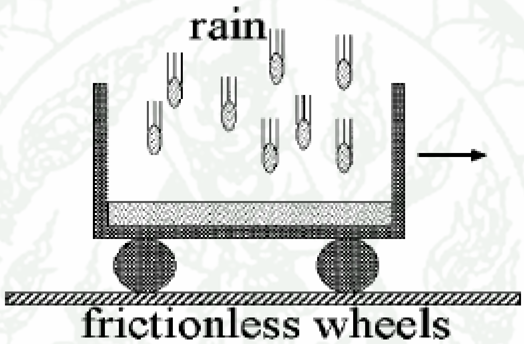

Figure 2 Rain drops are falling down into a moving cart.
Source: Singh and Rosengrant (2003: 616)

When compared to the 5/1 class, more effort was required to initiate and sustain the 4/1 students' discussion. It was not lively as many of them denied expressing their ideas. Nevertheless, the discussion was slowly continued by a few of them while the others participated by silently listening. By a show of hands, most 4/1 students believed that the cart would slow down because of its increasing weight, which causes an increase of friction (even though the problem states clearly that the surface is frictionless). Based on "v = s/t," a girl and her fellows argued that there is no mass in the formula, so the cart's velocity is constant. Using "p = mv" with limited mathematics ability, a few boys contended that the cart will move faster because of its constant momentum and its increasing mass. The discussion was ended while one of the boys, who believed that the cart will move faster, was challenging most of the students that the surface is frictionless, so it would not matter how much the cart weighs.

The researcher's reflection on the idea tried

The researcher was personally impressed by the students in both classes as they purposefully engaged in the discussions, which were different from what he observed in the first semester. Their discussions shared some productive aspects of an inquiry-oriented discussion (Hammer, 1995b: 421) in which the students, though not all, were finding key issues underlying the discussions; constructing arguments for the issues; connecting the arguments with other situations; and attempting to build a shared understanding. These aspects convinced the researcher that his idea—changing the way of questioning as well as that of reacting to student answers—could gain student classroom participation.

As an activity of collaborative action research, the researcher shared his reflection on the classroom events with Jantra and Sakchai. He also contributed ways for continuing the discussions with them. For example, in order for the 5/1 students to understand that the impact (or hitting) is a form of medium disturbance, the question of tearing a piece of paper had potential to introduce other forms of disturbance (e.g., bombing, rubbing, and blowing). For the 4/1 class, many of the students tended to believe that the more the cart's mass (and weight) increases, the slower it moves regardless whether or not the surface is frictionless. Moreover, in reasoning a phenomenon, they relied heavily on physics' formulas without conceptual understandings. Thus, it seemed necessary that the 4/1 students' understanding of force and motion needed to be further probed and developed.

The teachers' reaction to the researcher's suggestion

As noted by Brickhouse (1993), individual teachers have their own criteria to account for the success of each instruction, which may or may not be consistent with those in academic research. It became apparent in this study that Jantra and Sakchai did not consider the same aspects of the classroom events as the researcher did. Despite an agreement that student participation is valuable in an instructional process, Sakchai expressed his major concern about the content-time relationship as follows:

> If we teach this way (classroom discussion), I'm not sure how much content can be put into the mid-term test. … I know it (student participation) is good and I would do it if time is flexible. (Sakchai, Sixth group discussion, December 8, 2008)

This might not be surprising when considering data from the researcher's pilot survey study (Ladachart and Roadrangka, 2008) as a norm. In that study, twelve of seventeen informant physics teachers in this province, which included Jantra, spent 30 minutes or less in teaching sound production. More specifically, three of them spent 10 minutes only. This was opposite to the 5/1 class's discussion in which the students took over one hour but did not reach a shared conclusion of sound production. Considering only progress of covered content could make Sakchai reluctant to continue the discussion. He also added that, "There are a lot of things in books. Most of them are about calculation."

In a similar vein, despite the fact that the 4/1 students did not fully understand the concept of force and motion, Jantra felt reluctant to go back to teach content already covered There were other topics (e.g., work and power) that were waiting for her and the students to teach and learn. Furthermore, she argued that the classroom discussion was not so successful in gaining participation of all students. She said, "I saw some boys sitting in the back of the class were chatting." Seemingly, Jantra expected to see all students' participation from the researcher's first attempt.

Clarifying the different points of view between the teachers and the researcher

By consulting literature, Jantra's and Sakchai's denial of the researcher's suggestion to continue the discussions was understandable. Hammer (1995b: 427) explains this situation as follows:

> Teachers often feel a conflict. … On the one hand, they want to devote time to students' exploration and reasoning; on the other hand, they have a certain amount of material to "cover." … The conflict for teachers remains, of course, if we measure content-oriented progress by the number of topics we cover. (Quote in original)

To alleviate this conflict, Hammer (1995b) continues to suggest that teachers need to broaden their traditional view of content-oriented progress. They should not consider only an amount of covered content but also a process of knowledge construction. In this present study, it seemed essential to facilitate Jantra and Sakchai to appreciate the value of the students' construction of their own understandings—that is, they needed to hold a constructivist view of teaching and learning.

However, what was required urgently before this collaborative action research collapsed was not to promote Jantra's and Sakchai's views of constructivist teaching and learning. It had become clear to the researcher that a demonstration of a constructivist instruction in front of the classroom, as requested by Jantra and Sakchai, was not useful in terms of promoting their professional growth and instructional reform. Reconsidering and remodeling activities of the collaborative action research in a way that suited Jantra's and Sakchai's needs seemed more important at this moment. Guidance on this was best offered in the literature on beginning teachers.

Reconsidering the conduct of collaborative action research

Literature in education (Fuller, 1969; Fuller and Bown, 1975; Veenman, 1984; Adams and Krockover, 1997) has consistently indicated that beginning teachers[6] typically are concerned with themselves (e.g., ability in controlling the classroom, comprehension in content knowledge, and personal adjustment in school), and not

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[6] Beginning teachers may be classified differently in different studies. Based on Veenman's criteria (1984), Jantra and Sakchai can be considered as beginning teachers who have less than three years of full-time teaching experience.

concerned with the students' learning process. This is a developmental stage in which beginning teachers lie as they are forming personal images of themselves as teachers before shifting to more concern with student learning (Kagan, 1992). In this present study, it was reasonable to assume that both Jantra and Sakchai positioned themselves in this stage as it was evident in their talks about teaching in which they both took the role of teacher and that of student interchangeably (see Chapter IV).

Based on this assumption, to facilitate professional growth of beginning teachers like Jantra and Sakchai appropriately:

> … Needs such as security, affiliation, and self-esteem must be satisfied first before beginning teachers can behave as autonomous or self-actualized persons and respond more adequately to the realities of their circumstances in order to perform a successful and satisfying job. (Veenman, 1984: 165)

Moreover, "attempts to force a different focus of attention (from beginning teachers' developmental needs) may be misguided" (Kagan, 1992: 163). Consequently, the researcher began to realize that his suggestion of creating a classroom discussion with students in order for them to construct knowledge might not be appropriate for Jantra and Sakchai since it did not fulfill their developmental needs.

Similarly in action research literature, Mitchell, Reilly, and Logue (2009: 346) suggest that a strong benefit for beginning teachers to engage in action research is the "power and voice" given to them to help make informed decisions about their teaching when "confronting real problems." In coping with at-hand problems effectively, it tends to be technical and practical support, not reform-based recommendation, for which beginning teachers look (Ginns *et al*., 2001). Thus, taking advantage of being in a real classroom, action research is used potentially to help beginning teachers understand the complexities of teaching (Kosnik and Beck, 2000), prepare them to be reflective on these complexities (Ross, 1987), and develop their images of self as teacher (Rosaen and Schram, 1997).

Turning a focus to the teachers' classroom-based problems

Thus, in an attempt of renewing collaborative action research, the researcher asked Jantra and Sakchai to express classroom-based problems they each perceived in order to generate a discussion. The aim of the discussion was to collaboratively seek ways to cope with these problems. To do so, the researcher tried to create a safe place in which the teachers felt free to disclose their self-related problems (Goodnough, 2003), saying "We do this with an aim to help one another (find appropriate solutions). We just share our perspectives. It depends on the one who teaches finally to make decisions" (Researcher, Seventh group discussion, December 18, 2008). Under this condition in which the researcher tried to be more open and flexible, the teachers seemed more comfortable to initiate a discussion. Normally having been quiet, Jantra began to raise her classroom-based problem as follows:

> I observed each group while kids worked (on an exercise sheet). It was not what I intended and expected. I wanted them to discuss and think together. But, they worked individually on their own. (Jantra, Seventh group discussion, December 18, 2008)

Jantra's problem created a fruitful discussion among the participants. It became clear in the discussion that what Jantra wished to succeed was to engage students in small-group discussions, not a whole-class one as previously suggested by the researcher. In responding to this, Sakchai proposed some strategies in order for Jantra to deal with the problem. Obviously, his strategies primarily aimed to control students' behaviors. For example, he suggested Jantra to tell the 4/1 students, "Say opinions of the other. Do not say yours." For him, it was, "A way to control them to talk (with others) automatically." Jantra accepted Sakchai's strategies gently. Nevertheless, she attempted to reflect on her action and proposed a strategy for herself as follows:

> Today, I sent this (a set of information and exercise sheets) for all (students). If I only send this one (information sheet) for each group and let one of them (in the same group) read for the others. I'm not sure whether they will discuss more. (Jantra, Seventh group discussion, December 18, 2008)

Consequently, the researcher also shared his perspective regarding the nature and number of questions given in the exercise sheet, in order to evoke Jantra to consider a relationship between her action and its implication on students' learning behavior as follows:

> I sat near a group of students and I saw them looking at one sheet before writing down on the other one. … I guess they might worry that they could not complete it on time. (Researcher, Seventh group discussion, December 18, 2008)

During the discussion, the researcher began to appreciate the power of the conversation between Jantra and Sakchai as they attempted purposefully to deal with their "own" classroom-based problems. By sharing perspectives associated with the problem, it fostered collaboration between them, which had been rare since the beginning of the study. It also allowed Jantra—the problem owner—to reflect on her teaching practice with a view to improve. However, after gaining different perspectives from the others, Jantra tended to expect the researcher to make a decision for her. Refraining to do so, the researcher expected her, in turn, to make "defensible decisions" (Feldman, 1999) using a number of perspectives provided for the sake of her own class.

Appreciating the discourse as the conduct of collaborative action research

After the discussion, all the participants appreciated its usefulness and agreed to continue next time. To make such discussion more structured and hopefully useful, the teachers each decided to prepare a lesson plan based on their own ideas for discussion before and after its implementation. It was important to note that writing a lesson plan and reflecting on its implementation was not normally done by both Jantra and Sakchai. Nevertheless, they committed themselves to do so in order for the sake of improving their own teaching practices. Indirectly, but influentially, as the school was positioning itself to be a candidate of "King's Reward Schools," the teachers expected to use this opportunity to develop lesson plans whenever asked by the school's academic department.

Since Jantra and Sakchai taught different physics content in different grades, lesson plan discussions varied, depending on their interests such as content being taught, classroom situations, and students' work. The initial discussion, as it was structured, tended to take "a stance of expert consultation" (Nelson, 2009: 577) in which they each focused on their own lesson plan and expected the researcher to provide suggestions. During that period, there was little collaboration between Jantra and Sakchai. As they engaged longer in discussions, their collaboration became noticeable. In addition, since they discussed on particular issues many times, the nature of discussions was iterative. The following two subsections describe each teacher's engagement and learning separately. This is because Jantra's and Sakchai's major concerns were laid on different instructional aspects.

Jantra's Engagement and Learning

Discussing a lesson plan

To engage in a discussion, Jantra prepared a lesson plan named "power." As in the plan, she intended to begin the lesson by asking, "Moving the same distance, which of the following, a walker or a runner, will be more tired?" It was her intention to use an everyday-life question to begin the lesson. Using this question, she expected students to answer that the runner would be more tired than the walker because of the different duration each of them spent in moving the same distance. Giving the same distance, she also expected the students to know that work done by each of them is equal. As a result of the different durations as well as the equality of work, the students could be able to discern that the rate at which work is done (or power) by the runner is higher than that by the walker, resulting in the runner being more tired. She would use this line of logical reasoning to present the content of power (e.g., definition and formula).

Interpreting from the variation framework (Ling, Chik, and Pang, 2006; Marton and Pang, 2006), Jantra's question is based on assumptions that work each done by the runner and the walker are equal (invariant) and that the durations each of them spent are different (varying). The latter seems sensible while the former is quite unclear. Using animate bodies (the walker and the runner) may not be clear enough for the students to discern the invariance of work. In mechanically taking into account work done by the runner (or the walker), what object should be considered? And, what force exerts that object and causes it to move? Therefore, the question seems insufficient in providing a condition where the students could discern power difference. Thus, they may not be able to follow Jantra's line of logical reasoning that links the notion of being tired to the concept of power.

As the discussion was continued, it became apparent that Jantra rarely analyzed the target content in planning this lesson. She could not mention prerequisite knowledge (i.e., work, force, and motion) necessary for the students to understand the concept of power. In an attempt to help her analyze the content, the researcher suggested as follows:

> (Before teaching power) we may need to check if they (students) can write the forces acting on an object in a given situation. … Do they know if each of these does or does not produce work? (Researcher, Eighth group discussion, December 29, 2008)

Trying out the researcher's suggestion

As a result of the suggestion, Jantra added one open-ended item in her multiple-choice mid-term test which required the students to draw a force diagram of an object placed at rest on an incline plane. After testing, the item showed to Jantra that only a few of the 4/1 students could draw its force diagram correctly. It was this fact that attracted her attention as she disappointedly said, “I taught it already.” By asking some intimate students, Jantra described some of feedback she received as follows:

> They (students) told me that I teach quickly and they don’t understand. But, they can’t tell what they don’t understand. They said, “*We don’t understand all (content).*” Who knows what they don’t understand? (Jantra, Ninth group discussion, January 12, 2009)

Using a more-open form of assessment evoked Jantra to realize her students’ ability in following her instruction (Carter and Berenson, 1997). In dealing with this unknown situation, she along with the researcher attempted to figure out “what they don’t understand” by considering the force diagrams written by the students. Though varied and unclear, one outstanding theme was that many of the students ignored the normal force (N) or wrote it incorrectly. As a consequence, the researcher suggested that Jantra should investigate their understanding of force-diagram writing in more detail using several situation instances. The suggestion returned the original conflict back again.

> Researcher: If they (students) can’t write a force diagram, they may not understand (work and power). It is a basic principle of mechanical equilibrium also. Do you want to help them do this? Or, will you continue?
>
> Jantra: Go back to force? … I have only one month.
> (Ninth group discussion, January 12, 2009)

Paying attention to students’ thinking

Jantra eventually decided to go back to force with uncertainty that she might fail to cover the remaining content (i.e., power and mechanical equilibrium). She and the researcher worked collaboratively to design a number of static one-object instances for force-diagram writing. The students were asked to do this task as an additional assignment. In addition to walking around to monitor whether or not the students were working on task as normally done, Jantra was asked to do two more things. “See how they (students) write and ask why they write in that way” (Researcher, Ninth group discussion, January 12, 2009).

After observing the students’ force-diagram writing, Jantra noted what she found into a journal entry as the following list.

– Students don’t know the difference between “rough” or “slippery” surfaces.

– Students don’t know whether or not there is ‘mg’ when an object is placed on the ground.

– Students don’t know that there must be ‘N’ when an object is placed on the surface.

– Students understand that ‘mg’ must always be in opposition to ‘N.’

– Students sometimes add an unnecessary force into the system.

(Jantra, Journal, January 14, 2009)

It was important to note that the 4/1 students had experienced force-diagram writing and classical mechanics problem solving in both Sakchai’s basic physics and Jantra’s advanced physics classes in the first semester. Nevertheless, the above list clearly indicated that they rarely understood it. This tends to support what Kim and Pak (2002) put in the title of their study, “Students do not overcome conceptual difficulties after solving 1000 traditional problems.”

Jantra began to question the effectiveness of her own teaching in promoting the students’ understanding of physics content as she noted in the same journal entry, “Teaching so much (advanced) content doesn’t mean that students get it. Like a journey, I arrived. But, where did I leave them behind?” Additionally, she assumed that not understanding the content could make the students lose interest in her teaching as she wrote, “This may be a cause of why they come to the class late and why they chat while studying." As a consequence, Jantra began to look for a way in which she and the students could "walk together" on that journey.

Despite recognition that most of the 4/1 students did not understand force-diagram writing, Jantra was not sure about its cause. Most interesting for her was why the students understand that 'N' and 'mg' must be in opposition, which she never taught. In attempts to investigate a source of this so-called misunderstanding, Jantra came to know that some of the 4/1 students remembered it from an outside-school tutor. It seemed harder than normal, for Jantra, to teach against what they were unscientifically taught in addition to their experience-based preconceptions.

Attempting to promote students' understanding of normal force

By consulting literature particularly in promoting an understanding of normal force, it seems necessary to challenge the students' prior understandings using strategies such as bridging analogies (Clement, 1993), computer simulation (Finegold and Gorsky, 1988), and several-instance discussions to seek a valid explanation (Minstrell, 1982). However, due to pressure of the remaining content, Jantra preferred a shortcut. She considered direct instruction as appropriate by providing conditions indicative to the presence of particular forces (e.g., mg, N, external force, and friction). For example, if an object is in touch with a surface (e.g., ground and wall), there is presence of the normal force whose direction is perpendicular to the surface's plane. Sakchai supported this decision.

Results of implementing direct instruction were not successful in terms that many of the students could not write a force diagram correctly. For example, some students compromised what they learned from the tutor and from Jantra as shown in Figure 3. 'N' and 'mg' were still in opposition while 'N' was perpendicular to the surface's plane respectively.

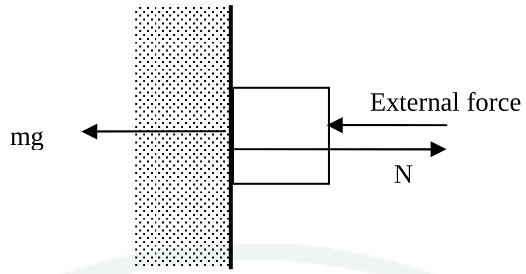

Figure 3 A force diagram drawn by a female student.

Jantra realized, “Just telling them doesn’t make them (students) believe (in physics content)” (Tenth group discussion, January 15, 2009). Nevertheless, she argued to implement it one more time. Consequently, all three participants of this study participated in designing instances for force-diagram writing again. During this process, although the researcher suggested the teachers use simple instances, it was by intention (and perhaps accustomedness) that they added more complex ones, such as dynamic two-object instances. Jantra argued for doing this later by saying, “If they (students) get this (force-diagram writing of complex instances,) mechanical equilibrium will be easy” (Twelfth group discussion, January 27, 2009). In other words, she looked forward to the remaining content.

After observing the students write force diagrams, Jantra came to share learning difficulties she encountered with the other two participants. For example, when the head of an arrow representing an external force directs *in* to an object at an angle to the x-axis, many of the students did not break or incorrectly broke it to x-axis and y-axis components. In facing events like this, she recognized limitations in her ability in explaining physics content to the students. As a consequence, she asked for suggestions.

Jantra: I can’t explain. I just know that it must be like this. If you (Sakchai) were me, how would you explain?

Sakchai: Can we tell them (students) to use the tail as reference?

Jantra: I did that. But, they don’t understand.

Researcher: After breaking, its components don't touch the object. So, they wonder how each (component) is related to the object.

Jantra: Yes. … It's hard to explain.

(Twelfth group discussion, January 27, 2009)

Knowledge/perspective sharing became often as Jantra raised questions in the group discussion. Her questions sometimes urged the participants to discuss about physics content more conceptually such as, "When one object is placed touching another object, is it necessary for a pair of (action-reaction) forces to exist" (Twelfth group discussion, January 27, 2009). Sometimes, she asked about assessment such as, "How can I assess a force diagram in which a student uses a dotted arrow (instead of a line arrow)" (Fifteenth group discussion, February 16, 2009). On some occasions, she raised a more critical issue such as, "The act says one thing and the (national) test assesses the other. Why aren't they consistent" (Eleventh group discussion, January 19, 2009). Some of her questions generated a seemingly-endless discussion while others ended with a few sentences.

Longer than average, Jantra had devoted six periods (approximately 300 minutes) for direct instruction and student practice about force-diagram writing. Nevertheless, many of the 4/1 students could not write a force diagram correctly, particularly on her complex instances. As a result, she decided to illustrate the notions that "force is abstract" and that an arrow is its symbolic representation, instead of repeatedly telling the students that there is force in a realistic sense. In doing so, she planned to use a real example by asking the students to weight a sand bag hung with a spring balance resting on a compression balance as shown in Figure 4. Also, in doing this, she wished to introduce the concept of mechanical equilibrium—the remaining content.

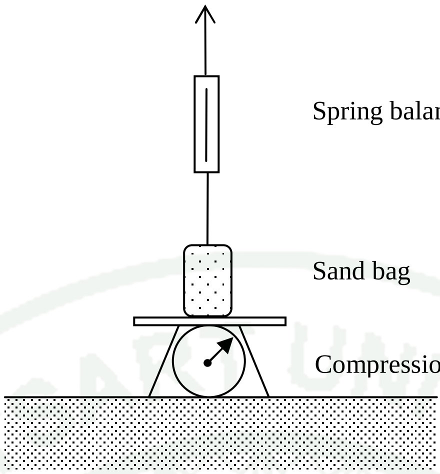

Figure 4 Arrangement of equipment used by Jantra to illustrate normal force.

As in her plan, Jantra intended to ask the 4/1 students to observe and record values shown on the compression balance (N) when varying a value read from the spring balance (T). Given the sand bag's weight (mg) is constant (invariant), she expected the students to discern a relationship between the values shown by each balance in terms of a linear equation—T + N = mg. Then, she would transform it to a symbolic representation. The normal force, which the compression balance acts on the sand bag, would be highlighted as it is equal to N.

However, the implementation of this lesson was not as easy as Jantra expected. Due to inadequacy in laboratory equipment, she had difficulty finding compression balances and, with the support of a chemistry teacher, she finally used Ohaus triple balances designed to weigh chemical substances instead. As this was their first hands-on physics activity, the 4/1 students were not comfortable with using both spring and Ohaus triple balances at the same time, as well as collecting and recording data. Limitations in mathematical ability also hindered them to determine the slope of a graph of N vs. T. Jantra echoed her discouragement as follows:

> I feel it's very hard. They (students) have studied that (traditional) way for a long time. It's hard to change within a short period of time. It may take a few years or more. (Jantra, Third interview, February 19, 2009)

As long as Jantra attempted to change her teaching practice in order to promote the students' understanding of force-diagram writing, she perceived resistance. According to her, the students "felt bored" to study the non-calculation content repeatedly.

> Physics is (numerical) problems. This is their (students') thinking. When they think of physics, they think of problems. Some asked me, "*Why don't you start with (solving) problems?*" They wait for problems. They don't even know what I'm teaching (force-diagram writing) is important. They think it's just an introduction. (Jantra, Third interview, February 19, 2009)

At the end of the second semester, Jantra perceived little success in promoting the students' understanding of force-diagram writing. Nevertheless, what seemed worthwhile for her were the insights gained about physics teaching as she engaged in collaborative action research. She expressed as follows:

> They (students) had told me that they don't understand my teaching. I hadn't ever known why. I used to ask myself whether it's me or them. Since I've engaged (in collaborative action research), Oh! I teach so quickly. I wanted them to get as much knowledge as I have. I hadn't cared whether or not they could get it. (Jantra, Third interview, February 19, 2009)

As a consequence, Jantra expressed that she realized the students' potential was a factor in physics instruction. Teaching students to understand something is not as easy as telling them once. Also, she committed herself not to teach them content that is too difficult or, in her words, "jump steps." She said, "We should teach according to the students' pace." Nevertheless, she was aware that a change in teaching practice can not occur easily. She still perceived the pressure of content coverage as well as the students' need of numerical physics problem solving since some of them frequently reminded her. In doing so, she needs time.

> It's impossible to change teaching within one year. It takes longer. Changing something needs time. (Jantra, Third interview, February 19, 2009)

Investigating students' pre-understandings of force

During summer months, Jantra (as well as teachers of other subjects) were assigned by the principal to teach a one-week course aimed to prepare "basic knowledge" for new incoming students who would study physics in the next academic year. In doing so, she chose to improve those students' mathematical skills by teaching unit systems (e.g., prefix, symbol, and unit change) and basic numerical manipulation. In addition, she exploited this opportunity to pursue her interest in investigating their pre-understandings of force. In the absence of Sakchai as he became a monk[7], Jantra along with the researcher interviewed three groups of five volunteer students after school using three guiding questions (Document, February 23, 2009) as follows:

1. When your science teacher says the term "force," what does it mean for you?
2. An object is placed at rest on the ground. Why doesn't it move? Is/are there force(s) acting on the object?
3. On a very slippery surface, three objects (A, B, and C) each are at rest, moving with a constant velocity, and moving with increasing velocity respectively. Is/are there force(s) acting on each of them?

Semi-structured interviews were employed to allow Jantra and the researcher to investigate the students' pre-understandings of force with some further probes. Focus-group interviews were used because some of the students were new to the school and the interviewers. Through these three interviews, results from a brief

[7] Becoming a monk is a religious commitment for Thai Buddhist men. It is a belief that a man has to go into the priesthood at least once, particularly after completing a degree and having a job, in order to repay an obligation to his parents.

analysis of responses produced by a few dominant students in each group could be summarized according to the questions (Document, February 27, 2009) as follows:

1. Force is something that causes an object's motion. Students tended to classify things into two groups: *active* and *passive*. Active things (e.g., people, animals, and wind) can exert force on other things while passive things (e.g., table, chair, and refrigerator) can not do the same. An active thing sends force into a passive thing in order to make it move—that is, an impetus view of force.

2. There is no force acting on the object. By no force, the students meant no "external" force—the force that an active thing exerts on the object. In this instance, they tended to classify force into two types: external and existing. An external (impetus) force is produced by an active thing while an existing force is already in nature (e.g., gravity and friction). The latter is also labeled as "pressing force," "resisting force," and "constant force."

3. Force acting on an object is directly proportional to the object's velocity. In other words, there is no (external) force acting on A; a constant force acts on B; and an increasing force acts on C.

Although these results were inadequate in terms of amount of data collected and methodology used (e.g., student sampling, development of the questions, and arbitrary analysis) for making a valid contribution to the public, they shared some aspects with the literature of students' alternative conceptions of force (Champagne, Klopfer, and Anderson, 1980; Minstrell, 1982; Halloun and Hestense, 1985; Alonzo and Steedle, 2009). Most importantly, they provided personal insights for Jantra to understand why the 4/1 students could not draw a force diagram correctly—taking for granted that the interviewee students and the 4/1 students shared some understandings of force.

In other words, in considering a surface (e.g., ground and wall) as a passive thing, the absence of normal force in a force diagram was not surprising. Or, when writing a force diagram, some students might consider only "external" force exerted by an active thing (e.g., pulling and pushing) as it causes motion—they ignored considering ‘mg’ because it is an existing force. Or, in according to these results, adding unnecessary force acting on an object that is moving with a constant velocity on a slippery surface was understandable. As a consequence, Jantra seemed to realize the influences of prior understanding possessed by students on their learning process. She reflected into a journal entry after the interviews as follows:

> Students have their own thoughts and understanding (of force). But, those are personal, not like scientific definitions. If a teacher doesn’t know (the students’ prior understanding of force), assuming that they will think in same way as the teacher teaches, there may be inconsistency between the thoughts of the teacher and that of the students. So, while the teacher teaches in whichever ways, the students will not understand. (Jantra, Journal, February 28, 2009)

Sakchai’s Engagement and Learning

Discussing a lesson plan

During the time that all three participants were seeking an appropriate way to engage in collaborative action research, the streams of content were flowing continuously. Since the first lesson-plan discussion was established, it was at this time that Sakchai planned to begin a new chapter. He described his lesson plan as follows:

> My new chapter is light. First of all, I’ll talk about use of light—how it’s useful in everyday life. Then, I’ll explain its nature and the history of light velocity measurement. (In explaining the nature of light,) I’ll shed light (using a flashlight) in directions to show that light travels in straight lines. Then, it is a talk about umbra and penumbra shadow. … (In teaching velocity of light,) I’ll link light to sound, which they (students) have studied. I may ask which of them has more velocity. Using an example of lightning and thunder, they’ll see that light is faster. (In teaching the history of light velocity measurement,) there are talks about methods each scientist used to determine the velocity of

> light. For example, Fizeau used mirrors. I have his formula already. (Sakchai, Eighth group discussion, December 29, 2008)

In addition to the content described above, in this two-period plan, Sakchai intended to present information about light, which included “photon as a particle of light” and “gravitational lensing: a process by which light is bent.” In other words, he planned to introduce “duality of light” to his 5/1 students in their first period of studying light. Jantra commented on Sakchai’s lesson plan no more than, “It’s good.”

In the discussion, it became apparent that Sakchai made little curricular decisions on what should and should not be taught. He could not defend why he decided to teach particular content in details (e.g., methods of light velocity measurement). It was an argument that he stated, “This content can either be taught or not. I saw it in books but it’s not a big part.” In other words, he rigorously followed content in tutor books[8], which mainly described information and numerical physics problems in order for students to achieve well for university entrance, in planning this lesson.

For the researcher, teaching too much content can lead to Sakchai’s deep-rooted problem of content coverage. Most importantly, it seems even more difficult, if possible, to effectively promote students’ conceptual learning of all such content within a limited period of time. Thus, the researcher suggested as follows:

> Students may be confused because you’re going to teach many topics. … My view is that you may need to make decisions. Choose ones you think are really important and focus on them. It’ll save you time as well. (Researcher, Eighth group discussion, December 29, 2008)

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[8] Citation of the tutor books used by Sakchai is intentionally omitted in this dissertation because there is no attempt to accuse these books of anything, which may result in problems. However, the researcher is quite sure that such tutor books are easily found in any book store in the context of this study and, perhaps, else where in Thailand.

Implementing the lesson with challenges by students

Classroom observation indicated that Sakchai did not revise or reduce his lesson after the discussion. He quickly implemented all steps, which included an introduction of the "duality of light," as he previously described. Being in a hurry while teaching, his explanations of light phenomena such as how light travels in straight lines and how umbra and penumbra shadow occur were superficially presented. As an outcome, some of the students asked questions and, consequently, some of those questions resulted in Sakchai's uncertainty in turn. He described one of those questions as follows:

> There are some students who read content beforehand. They asked, "*Light has diffraction, doesn't it?*" … It's quite difficult (to explain). (Sakchai, Tenth group discussion, January 15, 2009)

As noted in Chapter IV, Sakchai had limitation in the content knowledge and language difference between physics and everyday life, many times making him uncertain. Diffraction was one example. Using everyday life meanings, "light travels in straight lines" seemed contradictory to a meaning of "diffraction" as well as the definition of "gravitational lensing" Sakchai presented to the students. When asked about this contradiction, he could not provide a sensible explanation to his students. Of most concern for Sakchai was that his knowledge authority was being challenged.

Turning a focus to physics content

After Sakchai shared this concern to the group, a fruitful discussion about physics content was followed in order for him to effectively deal with students' challenging questions. In a discussion, it became clear that Sakchai did not understand diffraction of light scientifically. He exemplified the phenomenon as follows:

> *(Drawing a picture*) This is a door (of a room) and there is a light bulb inside the room. (Suppose that outside is absolutely dark,) we can see light passing

> through a space between the door's bottom edge and the ground. … It is diffraction of light because light partly diffracts the obstacle (door). (Sakchai, Eleventh group discussion, January 19, 2009)

Instead of diffraction of light, what Sakchai described seems to be reflection of light. In other words, light inside the room bounces off the ground and reflects to the outside by passing through the space. It does not mean that light diffracts without bouncing. Rather, diffraction of light is observably apparent when light passes a slit whose width is approximate to or smaller than light's wavelength, resulting in a high-low light intensity pattern on a screen behind the slit (Hewitt, 1998; Griffith and Brosing, 2009). When the researcher argued that the space between the door's edge and the ground might be too wide for a diffraction pattern to be apparent, Sakchai responded that:

> I don't know because I didn't study it in details. I have read several books and they provide this example. I'm not sure whether it's reflection or diffraction. (Sakchai, Eleventh group discussion, January 19, 2009)

Limitation in content knowledge influenced Sakchai not only in planning a lesson but also in implementing it. When he asked a question and many of the students contributed to the question, Sakchai could not capture, elaborate, or even critique their answers toward target content. For example, in responding to a question, "How can we measure velocity of light," a student answered, "We can compare it with velocity of a microwave because they are equal." This answer needs some clarification about how that student would measure the velocity of a microwave. Nevertheless, Sakchai simply accepted the answer without any response to it. Most of student contributions seemingly went into the air. It was paradoxical, for the researcher, in terms of why Sakchai taught advanced content even though he was uncertain with such content.

The answer became apparent. According to Sakchai, few high-achieving students[9] often asked him questions about physics content. He interpreted those questions as a way to challenge his content knowledge and test his capability. He did not want the students to lose faith in him, so he attempted to teach advanced content in order to show his capability with physics content. Noticeably, whenever Sakchai could not answer the students' questions, he hesitantly said, "*I don't know*". In hindsight, he once used to implicitly express this concern to the researcher;

> They (students) often ask (questions). They direct to me that, "*I'd ask you, teacher*." They'll be very satisfied when I can't answer. (Sakchai, Eighth group discussion, December 29, 2008)

A reason of why Sakchai was not comfortable engaging students in class discussion, as previously noted by the researcher, was understandable. What he wanted to be supported was physics content, not a reform-based instructional recommendation. As a consequence of this awareness, discussions with him were naturally turned into topics of how light phenomena (e.g., diffraction of light and lateral inversion) occur. Jantra was interested, attentively listening to the conversation, even though she made little contribution.

Discussing about physics content and what should be taught

In a discussion about the occurrence of umbra and penumbra parts of a shadow, Sakchai presented to the group a diagram as shown in Figure 5. Using the diagram, he explained in a tone of rote learning, how each type of shadow occurs. Moreover, he believed that for umbra and penumbra shadow to occur, it does not matter how small the light source is; it can occur even in the case of a light spot being the source. Additionally, as also in his plan, he would present definitions of "parallel rays," "diverging rays," and "converging rays" to the students.

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[9] By high-achieving students, the researcher refers to those, normally boys, who have performed well on numerical physics problems, as normally assessed by Jantra and Sakchai.

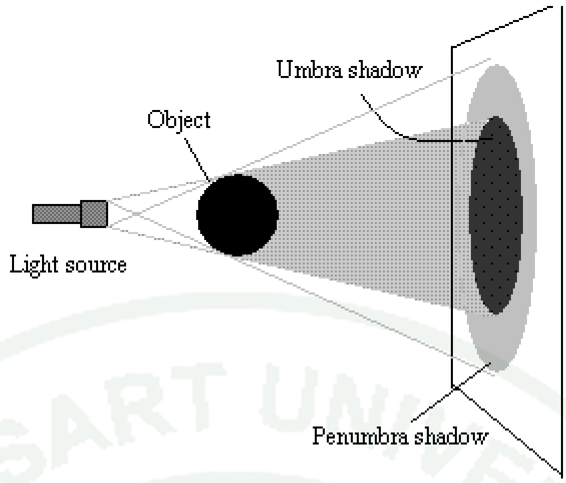

Figure 5 A diagram showing occurrence of umbra and penumbra shadow.
Source: Adapted from: http://phnote.blogspot.com/2007_04_15_archive.html

In attempts to engage Sakchai to think about the content more carefully and selectively, the researcher asked for a reason why he intended to explain the concepts of parallel rays, diverging rays, and converging rays. His answer was, "Just to know." It seemed that the "point-to-point light flux mapping conceptualization" (Galili, Bendall, and Goldberg, 1993) that light rays spread out from every point on the light source in every direction, resulting in the occurrence of umbra and penumbra shadows, was not held by Sakchai. To introduce this conceptualization, the researcher explained as follows:

> (For students to understand the occurrence of umbra and penumbra shadows,) they have to understand that all spots on the source emit out light rays in all directions. … When drawing this diagram, a book writer doesn't, and can not, draw all of them (light rays). He draws only few in the diagram. We have to know by ourselves that there are a lot more than what we see (in the diagram). (Researcher, Twelfth group discussion, January 27, 2009)

Jantra then made a relevant point as she asked, "Do students know that light rays spread out from all spots in all directions? … Should they need to know?" The former question underscores the importance of prerequisite knowledge of which a teacher should be aware when teaching particular content. (This was at the same time that Jantra was considering the ability in force-diagram writing as a prerequisite for studying work, power, and mechanical equilibrium). The latter question implies that a teacher has to be selective of what should be taught. However, at that moment, both questions were not what Sakchai was concerned about.

Sakchai needed to know how lateral inversion occurs—how light travels in order for lateral inversion to occur—as he was previously challenged by a high-achieving student. In a detailed discussion, it was surprising for the researcher to learn that both Sakchai and Jantra merely knew a general definition of lateral inversion as written in tutor books—left and right are reversed. In other words, they could not describe what the books actually mean by "left and right are reversed." Gee (1988: 300) argued that it was textbooks that have caused a myth of lateral inversion as follows:

> … The confusion (about lateral inversion) arises because the observer is tempted to rotate his or her frame of reference through 180˚ and to consider initially left and right directions when facing the mirror and to compare them with left and right when facing away from the mirror. Left and right may seem to have changed directions … the effect is caused not by the mirror but the observer's rotation.

After clarifying the myth of lateral inversion based on Gee's argument, the researcher demonstrated drawing a light ray diagram of image formation by a plane mirror using an unsymmetrical object instead of a symmetrical object as commonly used in tutor books. Based on the ray-tracing technique, the researcher emphasized that one point of the object results in only one corresponding point of the image (Goldberg and McDermott, 1987). After getting several points of the image, the researcher drew a line connecting each point together in order to form the image. Both teachers were encouraged to do so as well. Sakchai then echoed that:

> It's not in the books. Whenever I had studied, I was told to draw one point (before assuming how an image looks like). (Sakchai, Thirteenth group discussion, February 2, 2009)

After drawing, Sakchai came to know how lateral inversion occurs and why people call it that name. Then, he was presented with a basic notion that seeing a thing as a whole image is caused by combination of an uncountable number of light rays as perceived by a person. Consequently, the researcher turned Sakchai back into the issue raised by Jantra—being selective—as follows:

> We (teachers) can't teach everything. There's too much content in this world. You (Sakchai) must select what is basic, so students can use and apply it in their future. Don't worry that you can't cover all the content. It's impossible to cover everything. (Researcher, Thirteenth group discussion, February 2, 2009)

Sakchai was challenged to make a decision on Jantra's question—whether or not the students need to know that light rays spread out from every point of the source in every direction. Being convinced by two phenomena of light (occurrence of umbra and penumbra shadow and lateral inversion), Sakchai considered this explanatory notion as necessary. He eventually decided to "go back" to teach it in more detail. However, the decision was instantly made. Without detailed preparation, he taught such notion in accordance with his show-and-tell instruction.

Teaching with more emphasis on conceptual understandings

In doing so, Sakchai turned on a light bulb and asked the 5/1 students whether or not they could see light from the bulb. Then, he concluded immediately that light travels in every direction because all of them, who sat around the bulb, can see light simultaneously. Using an idea of light passing through holes of a curtain that emerged in the discussion, he then covered the bulb using a piece of purple textile and asked the students, "Explain what you see." Although answers varied (e.g., light changes color, light intensity is lower, light's not scattering, and light is smaller), Sakchai pointed out that light can pass through the uncountable holes of the textile, so light spreads out from every point on the bulb. He continued by explaining the occurrence of umbra and penumbra shadows based on the notion presented.

Similarly, when teaching lateral inversion, Sakchai asked the 5/1 students to draw a light ray diagram of image formation by a plane mirror using an unsymmetrical object as he previously did. He asked the students to use at least five or six points in order to form an image. He walked around to advise some of the students. Noticeably, the student, who used to challenge Sakchai, was proud of himself since he completed the task. He shouted out, “I know how lateral inversion occurs,” walking around to explain to the other students.

Sakchai perceived this event as successful. He felt a gain of faith from the student who challenged him. Besides, many of the female students did the task more actively—they rather enjoyed drawing than solving numerical physics problems. In pursuing this success, Sakchai tried to draw a ray diagram of image formation by a concave mirror, which would be taught later on, using the ray-tracing technique. He found that an image created by the concave mirror according to his ray diagram was not exactly consistent to a ray diagram shown in books. As shown in Figure 6, regardless of size and position, the image’s shape is not corresponding to the object’s shape. Rather, it is distorted by the mirror’s curvature.

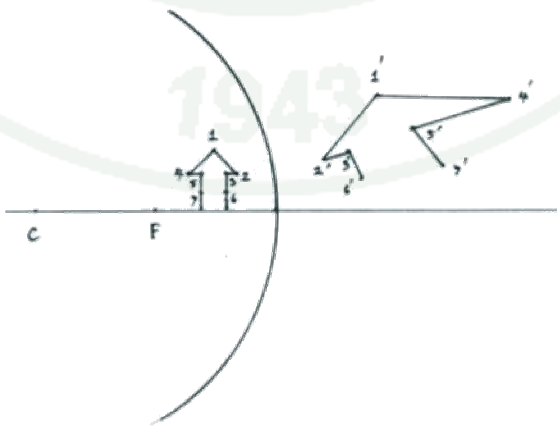

Figure 6 A light ray diagram drawn by Sakchai.

In an attempt to make this inconsistency clear before teaching, all the participants searched for empirical evidence on the internet. Finally, they found a picture as shown in Figure 7, which tends to support Sakchai's drawing of the light ray diagram. Whether intentionally or unintentionally, this inconsistency of a distorted image is typically ignored in common books while some of them clearly state that the image is "upright." Similar inconsistency was also found in the case of a convex mirror. In the discussion, the participants agreed that inconsistency shown in the books could probably lead students to misunderstanding. As a consequence, Sakchai began to realize the limitation of books in presenting particular content.

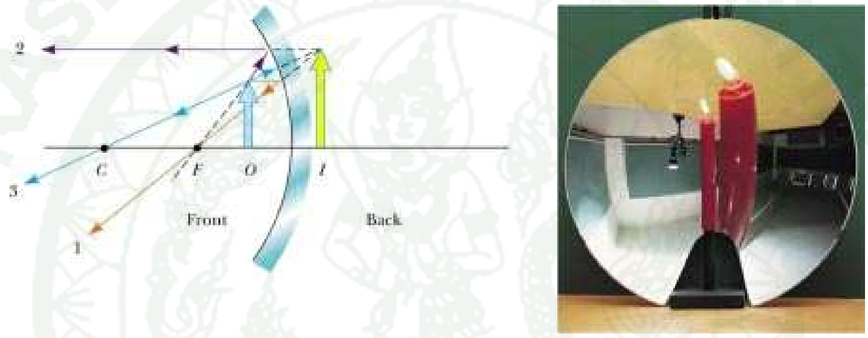

Figure 7 Inconsistency between a ray diagram and an image by a concave mirror.
Source: Adapted from: http://www.physics.byu.edu/faculty/rees/123/PPT/Class23.ppt

Sakchai did not hesitate to present this inconsistency to the 5/1 students. He asked them to draw a light ray diagram of image formation by a concave mirror using many points. His intention was to allow the students to discover the inconsistency by themselves. However, as drawing a ray diagram of image formation by a concave mirror was more complex and time-consuming than that of a plane mirror, as well as Sakchai being quite strict in unnecessary details of the diagram, another one of high-achieving students complained:

Student:	For what purpose do you need a beautiful diagram?
Sakchai:	To get one as similar to what we actually see.
Student:	(Ironically saying,) So people are drawing this when they are doing the entrance exam?

Sakchai: You have to understand the basics first. If you don't, how will you do the exam?
(Seventh classroom Observation, February 17, 2009)

While one group of the students, mostly who did not perform well on traditional assessments, enjoyed hands-on activities, a few high-achieving students favored numerical problem solving, so in turn Sakchai tried to balance needs of both sides. In doing so, he attempted to show consistency between an image created by drawing a light ray diagram and a value determined by using a formula ($1/f = 1/s + 1/s'$) in order for all the students to observe the validity of each method. During instruction, it was also noticeable that Sakchai was more aware of the limitation of a light ray diagram as a way used to represent purposefully some attributes of an image. He cautioned the students that:

> What you draw informs you only whether the image is bigger or smaller and whether it is real or virtual. It doesn't inform you that the image we see is the same as it (light ray diagram) is. It has limitations. (Sakchai, Seventh classroom observation, February 17, 2009)

Being aware of limitations in books and students' individual differences

At the end of the semester, as a result of engagement in collaborative action research, Sakchai had learned about physics content in deeper details than what he had read from books. He realized that what he showed in class sometimes was not consistent with what he told, and such inconsistency could create difficulty for students to understand it. Seemingly, this made him more interested in how scientific knowledge described in the books has come about. He expressed this as follows:

> Formerly, I've never taught in detail … I taught the same as the books. I'm not interested how it (scientific knowledge) comes. It (engagement in collaborative action research) helps me know several topics more in depth such as drawing a ray diagram. Since we'd (the participants) talked and

> thought together, I'm aware that what is taught and what is actually observed must be consistent. I had never observed this inconsistency before. When you (the researcher) asked me to draw, it's not what I'd understood. I'd overlooked it. Now, I discover what I don't know. (Sakchai, Third interview, February 20, 2009)

Besides, Sakchai seemed to appreciate that teaching is much more complex than telling all the content in books. He understood his role as teacher to be selective of what to be taught as well as how to organize it in an appropriate sequence for the students to understand. He expressed what he would first improve about his teaching practice as follows:

> First of all, I would organize a sequence of content. I don't want to follow what people prescribed (books). What should be taught first and what should come later? Order in according to its importance. I used to understand that, as content like this and this, a teacher must cover all. If not, seek additional time to complete it. … (In annually buying equipment,) I'd select equipment in the most important topics first. (Sakchai, Third interview, February 20, 2009)

Also, Sakchai was more aware of students' individual differences. He stated that repeatedly listening to a few high-achieving students influenced him to over emphasize numerical physics problem solving. He had ignored the voices of the other silent students who could not follow his pace of instruction. He committed himself to use hands-on activities that would serve female students' needs:

> Some of them, particularly girls, enjoyed (hands-on activities). As I talked with them (girls), they could follow (instruction). They'd like to explain what they think. … Some (high-achieving boys) didn't like it though. They wanted calculation only. It's common because we (teachers) can't only serve the needs of some students. … I used to tell them, "*I can't serve only one person's need*. *We have others who don't like calculation*." (Sakchai, Third interview, February 20, 2009)

The Researcher's Reflection

So long as Jantra and Sakchai had learned the complexity of physics teaching and learning as a result of their engagement in collaborative action research, the researcher had simultaneously learned the complexity of being a facilitator in order to promote their professional growth. It is important to note that not only did the professional growth of each teacher occur, as earlier noted, but also that of the researcher as an action research facilitator. Thus, in this subsection, the researcher discusses his experiences of being a facilitator. This is divided into two parts: *On facilitating action research for teacher development* and *On reforming science education through teacher development*. It is the researcher's hope that these will be useful, more or less, for those who wish to initiate collaborative action research and work with a group of (beginning) teachers in other Thai contexts in order to promote educational reform.

On facilitating collaborative action research for teacher development

As one may perceive, the researcher initiated this collaborative action research with a strong commitment to "get(ting) where (the teachers) want to get" (Kosmidou and Usher, 1991: 28). Later, he became aware that to implement this commitment, at least in the context of this study, needs careful consideration because the teachers initially engaged in collaborative action research had "a passive-learner stance" (Goldston and Shroyer, 2000: 333) and they tended to take their educational situation for granted. Under this condition, it was essential for the researcher, at that moment, to help the teachers "articulate where and what it is they want to get to" (Pedretti, 1996: 324).

In spirit of this professional development, the researcher explored the teachers' pedagogical concerns. It was a fact that their concerns were several, but to some extent, interrelated. As a consequence, the researcher tried to "stay small, stay focused" (McNiff and Whitehead, 2002: 85), suggesting the teachers to make progress on one particular aspect of those they showed concern. Shamefully to say, it became the researcher’s hastiness to see a significant change that made him strongly propose the teachers to increase students’ classroom participation. The teachers were reluctant in implementing his proposal even though it was one of their concerns. This was clear enough that, under the context of collaborative action research, “(the facilitator) could not direct the teachers” (Ponte, 2002: 416).

Due to such reluctance, reconsideration about how collaborative action research should be undertaken in an appropriate way was needed urgently. In pursuit of this, the researcher had struggled for a period of time in seeking an action research focus genuinely shared by the teachers. This was because some of the teachers’ concerns (e.g., content coverage and students’ performance on traditional tests) were not compatible with the researcher’s constructivist agenda (Coble and Koballa, 1996), resulting in a tension between the two sides. As the study went on, the researcher’s strong commitment of getting the teachers to where they wanted to get was gradually undermined since it brought him and the teachers into a “vacuum” situation—having no action research focus.

As suggested, a facilitator “must balance the needs of the entire group with unique educational contexts” (Pedretti, 1996: 324) in order to seek “a consensus … between what the teachers wanted to do and what (the facilitator) considered sensible” (Ponte, 2002: 416). In doing so, negotiation and debate on research interests with the teachers was suggested (Bello, 2006). Unfortunately, this seemed not so helpful, at that moment, because both teachers expected it of the researcher. As it happened once, to propose “something” was very challenging because the teachers would neither meaningfully implement nor argue on the proposal unless it totally or mostly fitted their needs. By hindsight, they reasoned for this silent resistance as follows:

> You (the researcher) are older, so I dare not make any argument. (Jantra, Third interview, February 19, 2009)

> I didn’t want to create contradiction. (Sakchai, Third interview, February 20, 2009)

This silent, resistant behavior is not uncommon and it can occur in a broader scope of schooling (Baum, 2002). More specifically, it may also be, to some extent, a result of Thai culture, which Hallinger and Kantamara (2000) call a "compliance culture" or Sinlarat (2005) calls a "knowledge-receiving culture," that influenced the way in which the teachers of this study engaged in collaborative action research. In a similar vein, Sahasewiyon (2004: 508), who had facilitated a collaborative action research project in a northern province of Thailand, noted as follows:

> … Since teachers in our (Thai) culture are taught to respect and obey elders' ideas, they do not feel free to argue or debate on any issues with which they disagree. … They just act on what the senior colleagues on their team say.

As a consequence of this silent resistance, which may possibly be reflected in other Thai contexts, it is worth note that the role of the university researcher(s) in leading or facilitating collaborative action research in Thai contexts still seems necessary if it is politically expected to promote the education reform movement (see Somekh and Zeichner, 2009). Under the leadership or facilitation of the university researcher(s), however local needs (e.g., teachers' concerns) must be taken seriously into consideration in initiating any action research models. Necessarily, it is a role of the university researcher(s) to seek and fulfill such local needs.

Thus, the researcher acquainted himself with literature on beginning teachers' concerns in order to adjust the focus of this collaborative action research to suit the teachers' needs. As noted by Fuller (1969), beginning teachers' self-concerns could be both overt and covert. Some of them, such as ones with the ability to control the class or students' misbehavior, are overt as expressed by Jantra. Others, like ones with self-adequacy on content knowledge, may be covert (perhaps unconsciously) as shown in Sakchai's case. Hence, during engagement in collaborative action research, a facilitator has to be sensitive in discerning any of the participants' concerns in order to provide activities that are appropriate or perceived as useful for them.

Once the researcher grasped the teachers' needs and concerns as well as provided appropriate (technical and practical) supports, it is evident that the teachers engaged in collaborative action research with some degree of autonomy. Using a more open form of assessment, Jantra began to purposefully inquire why the students did neither understand nor were interested in her instruction, leading to an awareness of their prior understandings of content taught. Beginning with students' questions (initially perceived as threatening), Sakchai restudied content being taught in deeper detail, resulting in an awareness of books' limitations in describing image formation created by curved mirrors. Both teachers demonstrated potential development as they began to appreciate the complexity of the teaching and learning process. Once the beginning teachers' self-concerns were alleviated, "It is possible to advance their action research into more emancipator concerns" (Ginns, *et al*., 2001: 130).

The degree of collaboration between the teachers was also the case. As earlier noted, the discussions at the beginning of collaborative action research were like expert consultations. Despite the researcher's encouragement, the teachers (especially Jantra) oftentimes denied to make contributions. With a well-established relationship later, Jantra reasoned for this as follows:

> The reason I have not expressed many opinions is because my (teaching) experience is less than (that of) the other (Sakchai). I dare not to suggest anything. (Jantra, Email, February 27, 2009)

In other words, Jantra felt risky in contributing "anything" to the group. It was her prior perception before this study that she felt blamed by Sakchai. As a consequence, her way of participating in the group was to humbly ask the others for suggestions instead.

Similarly, Sakchai hesitated to work collaboratively with Jantra on an action research focus at the beginning of this study. He simply reasoned that, "We (he and Jantra) often think differently" (Sakchai, First interview, July 9, 2008). In looking back to the past, he mentioned that collaboration between Jantra and himself had been rare.

> She (Jantra) is reticent. Normally, she hasn't talked to me. We're not so intimate to talk. … I may suggest more if I work with those whom I am more intimate. (Sakchai, Third interview, February 20, 2009)

One reason to understand the lack of collaboration may be that the relationship between the teachers is not strongly developed yet because they are both newcomers in the school. Being close physically (yet isolated mentally) "may have created a reluctance to critically question each other's practice" (Nelson, 2009: 569) because they will have to stay in the same lounge in a longer period of time than just the duration of this study. More theoretically, it may be what Anderson, Thomas, and Nashon (2009) called "metasocial metacognitive knowledge," which they used in service to sustain necessary social relationships. Alternatively, the researcher's initial expectation on their progress, which may result in a perception of competition among them, can not be ignored. Data (mostly collected in unconcealed conditions) are inadequate to make a strong claim.

Whatever the reason(s), the degree of collaboration between the teachers increased concurrently as long as their self-concern was alleviated. Collaboration began with some technical or practical tasks such as drawing a ray diagram to understand occurrence of lateral inversion, designing instances for students to write force diagrams, and searching for empirical evidence of image formation created by curved mirrors. Later, it was the teachers' questions that joined them together in more analytical and critical discussions on other aspects (e.g., interpretation of students' works, selection of content to be taught, analysis of tutor books' limitations, and critique of national assessments). Increased collaboration reflects "the multi-faceted nature of teacher development," which personal, social, and professional developments of individual teachers are interactive and interdependent (Bell and Gilbert, 1994: 495).

Since the relationship among the teachers was developed positively, it was possible that they might devote longer periods of time discussing a particular aspect more than the others. Although all of those aspects are worth being discussed as they are related to different domains of knowledge (Ponte *et al*., 2004), it is a caution from this study that a facilitator should consider carefully which aspect(s) of them could potentially promote the professional growth of each teacher. In this study, for example, time was spent on the national assessment regime only in helping the teachers' awareness of its influences on their teaching practices. Rather, more time was spent on discussions of students' force-diagram writing or scientific explanations of light phenomena to promote the knowledge of learners and content knowledge respectively.

The nature of reflection by the teachers also determined how collaborative action research progressed and subsequently their professional growth. As noted at the beginning of this chapter, Jantra's reflection was initially laid on students' behaviors, which contradicted her intention. In her initial reflection, although possible reasons of such contradiction were absent, it was clear that Jantra focused on students. With the perspectives gained from the group discussions, her reflection gradually shifted toward an analysis of relationships between her actions and subsequent classroom situations. On the problem that the students did not engage well in small-group discussions, for example, she wrote into a journal entry as follows:

> Questions in the work sheet are closed-ended and answers can be found in the information sheet. When each of the students came in front of the class, they read those answers. It was not natural. This could make them (the whole class) not interested (in what was being presented). It didn't help create a discussion. … What I want to improve is to change the questions to be more open-ended, … allowing them to share opinions. (Jantra, Journal, December 18, 2008)

Later, Jantra's reflection focused on students' learning process (e.g., how they write force diagrams). With such reflections, which were often extended from the group discussions, Jantra framed a problem, generated a view of improvements, implemented it in practice, and shared its results again in the group discussions. As a consequence, she grew professionally according to her interest as guided by self and collaborative reflections.

In contrast, Sakchai had initially reflected little on his own teaching as evident by unconsciousness about his question-like monologue (see Chapter IV). Once asked by the researcher to do so, he quantified his perception on classroom realities (e.g., to what extent he felt successful in teaching and how much he gained student participation) into five levels of Likert scale. As guided further by an example of Jantra's reflection, he then began to do some "descriptive writing" (Hatton and Smith, 1995) in which he reported what happened in the class with little, if any, evidence about and analysis of it. For example:

> I asked them (students) to see light that passes through (a hole on a piece of) paper. I used a textile covering the bulb, allowing them to see that light spreads out from all spots of its source. They can explain that light travels in a straight line, and know that only some of light passes through the textile … because they can't see it (light) clearly. They understand how light travels and gain additional knowledge in terms that light spreads out in all directions. (Sakchai, Journal, January 27, 2009)

Sakchai's journals focused mainly on his actions in making students learn, followed by his expected outcomes. Usually, he ignored a process by which students could or could not learn from his actions. As a consequence, in the exception of perspectives gained in the group discussions and his "emphasizing more on (particular content)," a view of improvement was rarely generated by Sakchai himself. Little change in his practice seemed to be a result of different views on content being taught, which he gained from the group discussions. Instead of self-reflection, it seemed to be social pressure that created such change. Retrospectively, Sakchai mentioned about this as follows:

When you (the researcher) suggested to me, I felt that you wanted me to try. So, I must try. (Sakchai, Third interview, February 20, 2009)

Thus, it is fair enough to note that Sakchai's professional growth (mainly on content knowledge) was initiated by external factors (e.g., students' questions, the researcher's suggestions, and perhaps Jantra's progress), not directed by his reflections. Until he gained feedback from some female students, an awareness of individual differences of students was finally noticed at the later stages of this study.

Theoretically, reflection is highlighted as a key element in any action research model (McNiff and Whitehead, 2002). It can be defined as "deliberate thinking about action with a view to its improvement" (Hatton and Smith, 1995: 40) whose nature and developmental process in individual teachers is unique. In regarding Jantra's and Sakchai's experiences in teacher preparation and prior professional development, they both had been limited in opportunities to develop a capacity for reflection. Thus, the difference in the nature of their reflection seemed affected significantly by individual orientations (Collier, 1999). When having been given opportunities and asked to be reflective through activities (e.g., oral interview, group discussion, and journal writing), Jantra's initial concern on students' misbehaviors as well as its revelation precipitated her to progress (Clarke, 1995). This was different to Sakchai whose initial concerns were covert or unconscious. Moreover, a strong focus on students' performance in the traditional tests limited Sakchai when he considered his own actions and classroom realities (Ward and McCotter, 2004). Nevertheless, it is worth to note that feedback from the students about ways they learn reinforced "a shift (in Jantra's and Sakchai's reflection) from the teacher's perspective to a pupil's perspective on learning" (Clarke, 1995: 252).

As demonstrated throughout the study, the researcher had played a number of roles in facilitating collaborative action research, including a thought challenger, a reflection and collaboration promoter, a discussion moderator/negotiator, a content teacher, and a moral supporter. Comparing to other studies (Feldman, 1996; Pedretti, 1996; Ponte, 2002; Goodnough, 2003; Capobianco, 2007), these varying roles seem dependent on participants, their shared interest(s), and a context in which they are working. Therefore, in a given context, a facilitator must be reflective in order to provide relevant supports, which are “sometimes unpredictable” (McLaughlin, 1990) to his or her participants. The ideal of “emancipator action research” (Carr and Kemmis, 1986) needs time and effort to occur, particularly in the context of this study.

On reforming physics education through teacher development

Although Jantra and Sakchai demonstrated potential development during one semester while engaging in collaborative action research, their teaching practice was still far from being called reformed, constructivist instruction. In other words, they still relied on the traditional instruction with concern about content coverage and numerical physics problem solving. Moreover, they sometimes exhibited a resistance to change such instruction when encouraged. In this part, factors that possibly influenced Jantra’s and Sakchai’s resistance to change instruction toward the education reform and recommendations are discussed.

Jantra’s and Sakchai’s view of knowledge transmission is one of the factors that hindered them to change instruction. This traditional view was evidenced in their lesson plans by a commonly-used phrase, “The teacher gives students knowledge about (intended content).” Though challenged in a regular manner by the researcher, it was robustly shown in the lesson plans throughout the study. Furthermore, at the later stages of this study, Jantra still argued for the use of lecture as follows:

> Let’s ask ourselves whether or not students learn (through lecture)? They do for sure, but not all. It doesn’t mean that they do not learn anything. It (student learning) occurs, but not 100 percent. (Jantra, Third interview, February 19, 2009)

In a similar vein, Sakchai showed some resistance to accept a constructivist view of learning. For example, when persuaded to think in a constructivist way that he had "constructed" knowledge about the inconsistency between an image formed by a curved mirror and its corresponding light ray diagram in books, Sakchai asserted that he did "discover" it. Still, he believed that the students could understand through only listening to his presentation, assuming that, "I think they (students) understand" (Fifteenth group discussion, February 16, 2009).

The examples above tend to support Koballa *et al*. (2005: 302) who contend that prior conceptions of teaching held by individual teachers are "resistant to change." Blanton (2003) as well as Volkmann *et al*. (2005) explain this robustness occurs because the view has been developed or "modeled" since teachers participated as students in the traditional format of education. To change it, Feldman (2000: 613) suggests, based on a conceptual change model, that teachers may accept reform-recommended instructions, "if they are *discontent* with their old practice … and they find the new ones *sensible*, *beneficial*, and *enlightening*" (Italic in original). The case of Jantra tends to support this suggestion as she began to accept that prior understandings held by students hindered them to scientifically draw force diagrams after having been trying to lecture them, but not so successfully.

Besides the robust view of knowledge transmission, the lack of conceptual understandings of content being taught led Jantra and Sakchai to have difficulty in analyzing what important aspects of that content are and which of them should be taught accordingly (Gess-Newsome and Lederman, 1995; Kapyla, Heikkinen, and Asunta, 2009). Consequently, it became even more difficult for them to transform intended content into a form that is comprehensible to their students, even though they knew some instructional strategies (e.g., jigsaw). In other words, limitation in content knowledge was an obstacle for them to teach it in other meaningful ways. Under this condition, presenting content in the same or similar way as it is described in books (e.g., definition of terms and formula) seemed to be their most appropriate choice.

Although Jantra and Sakchai had participated in professional development activities (5Es inquiry cycle and authentic assessment), those activities aimed mainly at developing their pedagogical knowledge. Carlsen (1993) argues that training pedagogical strategies to teachers without an emphasis on content knowledge might be a wasted effort since they might not be able to implement purposefully the strategies in real classrooms. This is evident in case of Darika, who has long teaching experiences but is limited in physics content (see Ladachart, Nashon, and Roadrangka, in press). Therefore, instead of introducing content-free pedagogical strategies, those responsible for teacher development to promote the education reform may need to fundamentally consider teachers' content knowledge and then help them transform particular content with other domains of knowledge into an accessible form for students (Shulman, 1986; Geddis *et al*., 1993; Magnusson *et al*., 1999). It is potentially apparent in this study that when Sakchai felt more certain with the content being taught, he began to generate his own analogy about image formation by point-to-point light ray mapping as follows:

> It's like when you (student) wrote 'Gor-Gai' (the first letter in the Thai alphabet) since you were in the elementary level, there're many points and you connected them together (to form an entire image). (Sakchai, Sixth classroom observation, February 10, 2009)

Feedback from students who normally achieved well in traditional instruction was a factor that made Jantra and Sakchai hesitate to change their teaching practices. These students preferred to study physics through lecture, enjoyed numerical physics problem solving, and did not want to engage, or passively engaged, in activity-based instruction. Moreover, as earlier noted, they sometimes reacted in a negative manner to Jantra's and Sakchai's attempts to change instruction, arguing that the activities provided would not help them fully succeed in the university entrance examinations. Inevitably experiencing resistance by these students whilst trying to change instruction made Jantra and Sakchai disappointed.

Tsai (1998, 1999) suggests that students' preference of instruction may relate to their epistemological beliefs—beliefs about the nature of knowledge and ways of learning such knowledge—and that students who hold different epistemological beliefs tend to perceive and interact with the same instructional activity differently. In a similar vein, Hammer (1995a: 398) noted that a physics course that "typically begin(s) with a review of mathematical formulas and procedures … may reinforce, if not produce, a belief that physics reasoning is symbol manipulation." In the cases of Jantra and Sakchai who had emphasized numerical physics problem solving, it is possible that the students who resisted their attempts to change instruction tended to hold epistemological beliefs that count "(physics) formulas and procedures as knowledge" (Hammer, 1995a: 406). With a epistemological mismatch, "it is not simply a matter of beginning to teach in a constructivist manner (and) one can expect complex processes to occur in … the classroom" (Roth and Roychoudhury, 1994: 27). Jantra raised this issue as follows:

> When asked to do the experiment (about weighting a sand bag), a girl did nothing. She said it's not calculation. It's necessary to change students' thoughts (about physics and ways of leaning physics) also. (Jantra, Third interview, February 19, 2009)

Therefore, besides supporting and encouraging teachers to change instruction in accordance to the education reform, it seems necessary for those responsible with teacher development to seek ways to help make the teachers aware of and deal with the differences in students' epistemological beliefs (e.g., constructivist and empiricist-objectivist). It was evident that even science educators such as Hammer (1995a) and Roth (1997) had experienced types of difficulties in dealing with this epistemological difference when teaching in classrooms. In a short term, as Sakchai demonstrated in this study, accommodating students' learning preferences and ways in which they should interact with a prepared activity seems necessary (Roth, 1997). In a longer term, epistemological beliefs held by individual students need to be explored and made explicit for discussion with their teacher in light of a contemporary view of the nature of science. The latter was not done in this study because the nature of science was not in Jantra's and Sakchai's interests even though they possessed some of "the myths of science" (McComas, 2000). Furthermore, the importance of metacognition in monitor and control learning needs to be emphasized to both teacher and students (Brass, Gunstone, and Fensham, 2003).

In addition to the contextual factors, particularly the national accountability, noted in the preceding chapter, an event during the study could negatively influence Jantra and Sakchai, changing their instruction, and perhaps, the education reform movement as a whole. This event was that the school launched a one-week tutorial project whose aim was to enhance students' performance on national tests (ONET and A-NET). In doing so, five tutors from each subject, including science, from a private institution in Bangkok were hired to teach at the school. Most of Jantra's and Sakchai's students (500 approximately), who each paid 500 Bath, attended the project. All of them, which included grade 10, 11, and 12 students, studied together in the school's meeting hall.

One day was spent for science content, which included biology, chemistry, physics, astronomy, and geology. While teaching, the science tutor presented the students content, used a number of tactics (e.g., songs and easy-to-memorize phrases) to help them easily memorize it, convinced them what content would be in the tests, and occasionally introduced pornographic gags for their laughing. As in part of physics content, for example, the tutor presented a tactic as follows:

> You all (students) know that each item will provide a set of numbers. You just plus, minus, multiple, divide, or do whatever with those numbers. Then, you will get a "beautiful" one corresponding to one of its choices. Select that one. … Physics problems are very easy. (Tutor, Classroom observation, February 4, 2009)

Many of the students paid attention to the tutor's lecture and took notes of the tactics presented. They seemed enjoy the lecture as evident by their participation when asked by the tutor. One of them, for example, said to Jantra that he did "learn a lot." However, the students' interest in studying physics content as markedly exhibited during the project created a dilemma for Jantra. After this project for a week, she personally asked the researcher as follows:

> Is that kind of teaching good? … If not, why did students prefer it? … Why did (a student) say that he learned a lot from that kind of teaching? (Jantra, Personal conversation, February 12, 2009)

It was a disappointed feeling mixed with wonder that Jantra experienced. She felt that she had tried hard in her physics class but not even gained interest from the students. Oppositely, one outside tutor came to the school in one day and achieved it perfectly. Jantra's questions may reflect a developmental process by which she was forming a self image of what kind of teacher she would, and want to, be. As one may guess, an uncritical teacher may decide to easily follow or adapt this kind of teaching as he or she superficially perceives students' increased interest and participation. To overcome this dilemma, Jantra needed to answer those questions, which, "It depends on what (she and her students) mean by learning physics" (Researcher, Personal conversation, February 12, 2009).

It may be illustrative to use Chang's (2005) four-year attempts in implementing constructivist instruction in her physics course in order to better understand Jantra's and Sakchai's difficulty in changing their instruction. However, this is not a comparable case when considering Chang's academic background and context as she has strong physics knowledge, commits herself in constructivist teaching, and teaches university students. What seems to be similar is a difficulty experienced by them, all three instructors, during the first year of constructivist-teaching attempts. Chang (2005: 419) noted as follows:

> … the first year of the teaching innovation failed to fulfill the objective of introducing constructivist perspectives, and lost the existing strength of the transmission perspective. The unsatisfactory results revealed the complexity and challenges of innovative teaching, which instructors may encounter.

This is not a way in which the researcher of this study uses to legitimate the difficulty faced by Jantra and Sakchai. The point is that, to change instruction toward constructivist perspective, "improvement was neither linear nor straightforward. …

Conscientious and persistent modifications based on feedback from classroom implementations are essential" (Chang, 2005: 420). In doing so, "critical reflection" (van Manen, 1977) on personal limitations and contextual influences is essential for any teachers who wish to change their instruction, especially when they work under the traditional culture of education.

Summary of the Chapter

The chapter describes ways in which two beginning physics teachers had engaged in collaborative action research with facilitation of a beginning action research facilitator—the researcher. It highlights that collaborative action research, which is used in the study as a means to teacher development, has to lay its focus upon the teachers' concerns in order for them to cope with classroom-based problems. In doing so, the teachers need perspectives and supports associated with their close at-hand problem in light of the education reform, which allow them to reflect on the problem and then make instructional decisions appropriately. Once their concerns are fulfilled or alleviated, the teachers emphasize more on the students' learning process and begin to consider instructional changes. Factors that influence the ways in which the teachers engaged in collaborative action research and instructional changes are also discussed in the chapter.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

This chapter provides conclusions of the research. Then, recommendations of the research with respect to the use of collaborative action research for teacher development follow. At the end of the chapter, suggestions for future research are presented.

Conclusions

Problem Areas

The present research aims to examine the possibility and potential of using collaborative action research as an alternative approach to science teacher development in a particular context of Thailand. The research is derived from the lack of success of the traditional teacher development approaches in reforming science education at the school level. It is argued that the traditional approaches have a too simplistic assumption that teachers will change their teaching practice after being introduced to reform-mandated instruction. Rather, instructional change requires the teachers to be actively involved in a process of reconciling existing beliefs about teaching with the reform-mandated instruction in order to reconstruct a new way of teaching that is feasible in their context. Thus, collaborative action research is proposed as an opportunity where the teachers become involved in that process.

Research Framework

In this research, collaborative action research is considered as a regular discourse where a group of physics teachers and the researcher work together in improving teaching practice in response to Thailand's science education reform. Within the discourse, the teachers come to share their reflections as they make meanings of classroom experience while the researcher contributes more "theoretical" perspectives. Through perspective sharing, the teachers and the researcher then decide to take appropriate actions to improve physics teaching practice in a given context. Once the actions are taken, the teachers bring back the results of the actions for further reflection and improvement. Thus, collaborative action research becomes a cyclic discourse where the teachers and the researcher learn together through a process of translating theory (or reform policy) into classroom practice.

Participants and Methodology

The research involves four volunteer physics teachers from three secondary schools. The teachers consist of two experienced females, one beginning female, and one beginning male. The two beginning teachers work in the same school. The research is designed into two consecutive phases. Each phase takes one semester (approximately four and a half months). In the first phase, the researcher aims to understand teaching practices of the teachers and develop research relationships with them. In the second phase at which the two experienced teachers withdrew from the research for personal reasons, the two beginning teachers and the researcher come to initiate and engage in collaborative action research. The research is guided by two research questions formulated according to the research phases as follows:

1. How do the physics teachers conduct teaching practices in their context?
2. How do the physics teachers engage in collaborative action research and learn to improve their teaching practices in response to the education reform?

Naturalistic inquiry (Lincoln and Guba, 1985) is used as a research methodology to collect qualitative data with minimized attempt to manipulate the research setting. A variety of data collection methods include teacher interview, classroom observation, group discussion, and a collection of materials. In the first phase, the researcher acts as a non-participant observer in order to avoid his disturbance on teaching practices of the teachers. Nevertheless, he gradually becomes more involved and develops a research relationship with the teachers through interviews and informal conversation. In the second phase, the researcher engages in collaborative action research with the two beginning teachers. He acts as a facilitating member and as a participant observer using an emergent design to collect and analyze data in an ongoing, reciprocal manner to generate working hypotheses. Through prolonged engagement and rapport, the researcher has access to credible data from the teachers. A number of techniques including peer debriefing, triangulation, and member checks are also used to ensure creditability of the research results.

Conclusions in relation to the first research question

To achieve the first research question, the researcher considers teaching practice conducted by the teachers as a result of an ongoing process by which they each have made meanings of experiences of involvement in the school of science, whether or not they are conscious of that process. Thus, the researcher elicits their personal conceptions of teaching and of science with regard to their educational backgrounds through individual interviews. The interview data is then used to interpret teaching practices of the teachers as exhibited in actual classrooms. Results from this phase show that the teachers employ content-driven instruction that emphasizes numerical physics problem solving. They aim to help students master test-taking skills for future education at university level. This traditional way of physics teaching is influenced by both personal and contextual factors such as personal conceptions of teaching related to prior school experiences, limitation in content knowledge (including the nature of science), the national assessment regime, availability of laboratory equipment in schools, and students' learning preferences.

Conclusions in relation to the second research question

Collaborative action research was initiated in order to address the second research question. In doing so, the two beginning teachers and the researcher regularly met at least once or twice a week throughout a semester. At the beginning, it was evident that collaborative action research struggled with attempting to find its focus shared by all the participants. This was because the teachers engaged in collaborative action research with a number of concerns; however their self-concerns were less likely to be made explicit. Once the researcher introduced an instructional idea consistent with constructivist perspectives, the teachers initially tended to accept the idea. However, they denied implementing the idea later when they perceived that it did not meet with their concerns. As a consequence, collaborative action research almost ended lifelessly; nonetheless regular meetings and the researcher's ability to be more open to listen to the teachers helped it continue.

Collaborative action research was continued in a meaningful way after two months of struggling. Its developmental process gradually suggested that the needs or concerns of the teachers must be treated as the highest priority. It was the process of fulfilling the needs/concerns that intrinsically encouraged the teachers to engage in collaborative action research. For example, one of the teachers became enthusiastic in investigating students' thinking when she wanted to know why they did not perform well on a test, while the other teacher became interested in a conceptual understanding of physics content when he had to deal with students' challenging questions when perceived as threatening. Fulfilling these needs/concerns allowed the teachers to purposefully engage in collaborative action research, and this process led them to subsequent learning associated with their needs/concerns.

The teachers' needs/concerns shaped the way in which they engaged in collaborative action research, and then this way influenced their learning. The teacher interested in investigating students' thinking spent a good deal of time analyzing their work on exercises, and she came to a realization about students' prior knowledge as well as possible ways to overcome it. In contrast, the other teacher who was often challenged by high-achieving students' questions about physics content had paid more attention to conceptual understandings of the content in order to respond to the challenging questions. Once he better understood the content, he began to develop his own way of content presentation, not simply following the textbooks. It seems potential that change in teaching practice occurs when the teachers' self-directed learning is continued.

Although collaborative action research was eventually continued to promote teacher learning, there were other factors, in addition to the teachers' needs/concerns, also influencing its conduct such as the nature of teacher reflection, group culture, relationships among the participants, and contextual conditions. These factors made collaborative action research unique. Therefore, results of the research can not fully be generalized to other contexts. The readers have to determine the relevance of the results in their own contexts. The next section provides the recommendations for the use of collaborative action research as an approach to science teacher development.

Recommendations for Conducting Collaborative Action Research

This section provides the recommendations of the research. Before making any remark, however, it is important to repeat that collaborative action research as demonstrated in this research is potential and possible to be used for promoting the science education reform in Thailand indeed when its focus is adjusted to meet the teachers' needs/concerns. By potential, it is meant that learning from engagement in collaborative action research can support the teachers to initiate a change in teaching practices even though their attempts may be resisted and unsuccessful. By possible, it is meant that the regular conduct of collaborative action research can be fostered among Thai teachers; nevertheless initial intervention, extended effort, and time are necessary to make it possible. In what follows, the recommendations for the use of collaborative action research as an approach to science teacher development in Thai contexts are discussed.

First of all, it is important to note that the present research has pointed out a number of factors, both personal and contextual, that hinder the teachers to teach in other ways than the traditional approach of presenting information and demonstrating numerical physics problem solving. Although not exclusive, these factors include conceptions of teaching, limitations in content knowledge including the nature of science, ability in transforming content into teachable forms, and contextual influences. These factors are interrelated in some ways and act as "a conservative force" (Tobin and McRobbie, 1996) that sustains the traditional practice. Therefore, teacher development approaches emphasizing one fragmented instructional aspect are not effective enough in supporting desirable change. Rather, to make "significant and worthwhile change in teaching practice" (Richardson, 1990), teacher development in Thailand should be viewed as a way to promote ongoing teacher learning through reflecting on and inquiring into teaching practices with consultation of research-derived knowledge.

In the regard to this view of teacher development, teachers' ability to reflect on their teaching practices and subsequent student responses becomes influential in shaping their learning. However, it is the fact that the teachers of this research had not been supported with reflective ability until they engaged in collaborative action research. Although the results from these two beginning teachers should not be inferred further to other beginning science teachers, it is worth suggesting that reflective ability should be persistently promoted for all pre-service teachers because such ability can not be developed overnight. Once they become practicing teachers, they can critically reflect on the complexity of experiences in classrooms in order to make meaning of those experiences for their continuing professional growth (Rodgers, 2002). Action research can serve as a context for any practicing teacher to reflect on and learn from teaching experiences. It is likely to be more productive when a group of teachers and educators who have a range of perspectives come to share their reflections within the discourse of collaborative action research.

In building collaboration among teachers and educator(s), mostly acting as the facilitator, "it is important that all participants hold or develop a similar perspective on learning" (Erickson *et al*., 2005: 795), so they can have common language as well as shared purpose in their discourse. However, such agreement may not naturally exist in some collaborative projects particularly when the educator holds reform-based perspectives, which are new for teachers. Moreover, the teachers may expect the educator to direct them in some particular direction while the educator wishes to empower the teachers to control the content and process of the project instead. It becomes "the agenda-setting dilemma" (Richardson, 1992) that the educator may have to encounter. At this moment of building collaboration with the teachers, it is crucial for the educator to embrace any dilemma or even conflict into the discourse in order to explore and manage it with teachers. The dilemma or conflict is an inherent element in any collaboration, which can create the context for learning (Achinstein, 2002).

In addition for the educator working collaboratively with teachers, what seems more crucial than encouraging the teachers to appreciate reform-based perspectives and practices is that “the (collaborative) project must meet the real and existing needs of all participants” (Erickson *et al*., 2005: 795). As demonstrated in this research, collaborative action research can continue only when it is adjusted to meet the case teachers’ needs and concerns. However, what becomes challenging is that the teachers’ needs and concerns may be unintentionally overlooked particularly when the educator is strongly committed to seeing a change towards the reform-based practices. Thus, the educator may have to keep in mind that “change in practice will not occur if certain personal conditions for the participants of change are not met” (Baird *et al*., 1986: 136). What the educator has to do is to sensitively discern the teachers’ needs and concerns, which are sometimes covert, and thus to propose possible yet critical perspectives derived from research-based knowledge in order to fulfill those needs and concerns. Importantly, it is crucial that the teachers must feel free to accept or reject all of what is proposed.

In collaborative action research, teacher learning is mainly constituted within a context of what Little (2003) refers to as “representation of classroom practice.” It is the facets of classroom practice that one participant teacher makes visible in public discourse and to what extent he or she opens up or closes down opportunities to gain perspectives from others. In this research, teacher learning is constrained in many instances with unreflective self-concerns when the case teachers focus on what they have done and overlook other significant incidents (e.g., students’ responses) happening in the classroom. Since some teachers may not be familiar with reflecting in and on their teaching practices, it is crucial at the beginning for the educator to help them prepare some representation to be resources of public discourse. Lesson plans can serve as a starting point for productive discourse. Moreover, the presence in the classroom of the educator can help the teachers to recall some classroom events. When purposively done, these can ensure that productive discourse, rather than common chitchat, will exist in collaborative action research.

One feature that possibly relates to teacher representation of classroom practice is relationships among all participants in collaborative action research. In the present research, the teachers initially hesitated and sometimes were reluctant to make their teaching practices visible in public discourse; thereby they felt risk in uncovering their weakness in those practices. Without detailed representation, productive discourse is less likely to exist in collaborative action research. Thus, an atmosphere of mutual trust and respect becomes necessary to allow the teachers to freely engage in public discourse with less anxiousness. Of course, this atmosphere can not be developed quickly but gradually. It is the educator who facilitates collaborative action research to create and nurture such an atmosphere by modeling how to value and respond to teacher contributions just as a way in which a teacher facilitates productive group discussions by students (e.g., van Zee, 2000). Although, this critical role is not pragmatically easy, long-term engagement in that atmosphere could help.

Organizational tasks are one other issue that affects the conduct of collaborative action research and, consequently, teacher learning in actual context. In the present research, although the teachers and the researcher had regularly met approximately once or twice a week, there were times one of them could not participate in some meetings due to other responsibilities. Given this fact, particular action research models/cycles (e.g., planning, acting, observing, and reflecting) are less likely to be followed. Therefore, it is crucial to ensure that the key feature of action research practice (i.e., reflection) is maintained by the teachers instead of a concern with following or completing the cycles. With this regard, the conduct of collaborative action research should be seen more like "a reflective 'journey' than a process of implementing a 'fixed' set of ideas" (Mokuku, 2001: 197). However, on such a long journey of learning, a close liaison between the teachers and the educator could continue their collaboration in certain directions (Erickson *et al*., 2005).

One important fact is that collaborative action research, once established, usually needs extended effort and time in nurturing it in a meaningful way to teachers. It is assumed with hope that the teachers will gradually take control of and learn from its content and process at their own rate. This is very opposed to the traditional approach of teacher development that emphasizes assessment of desirable outcomes at particular points in time. Hence, those interested in building and sustaining it should not over expect to observe significant change in teaching practices of participant teachers, particularly at the beginning. Moreover, reflective practice is essentially required for them to work collaboratively with teachers. In doing so, a summary of guiding principles for using collaborative action research as an approach to teacher development can be provided. That is, those interested in building and sustaining collaborative action research for teacher development should:

– view teacher development as an ongoing process of teacher learning where they reflect upon and inquire into their teaching practices;

– encourage and facilitate reflection by teachers, so they can come to a better understanding of their teaching situation;

– be sensitive in discerning needs and concerns of teachers and try to fulfill those;

– establish teacher collaboration through sharing reflection, perspective, and practical knowledge as well as nurture an atmosphere of mutual trust and respect by valuing teacher contributions;

– keep in mind that dilemmas, tensions, and conflicts are very common in collaboration, so those need to be explored and managed with the teachers;

– keep the teachers in contact and organize collaborative discourse convenient to them; and

– feel free to see the teachers growing at their own rate.

Suggestions for Future Research

Although this small-scale research has demonstrated that collaborative action research can be potentially used as an alternative approach to science teacher development, research that investigates its long-term impact on teachers as well as researches in other Thai contexts is still needed. In this regard, that research should identify relationships between teacher experiences and their learning as well as influential factors on the relationships more systematically in addition to providing anecdotes. More accurate claims are important for a guarantee that the promotion of collaborative action research in a broader scale, which needs more effort and budget, will create observable effects in Thailand's science education reform. Also, there is need for research identifying particular conditions or mechanisms under which collaborative action research is organized and maintained in Thai contexts.

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APPENDICES

Appendix A

Interview Items

Interview about educational background, conceptions of teaching, and conceptions of science

Date: ____________

Name: _____________________________

Interviewer: _________________________

Interview context:

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First Interview (educational background and conceptions of teaching)

1. Could you tell me about yourself by stating your name, your school, your responsibilities in the school, your personal and educational background, and so on?
2. Could you tell me about how you decided to become a science teacher?
3. Could you describe your achievement in science and physics, in particular, when you were a student? In your opinion, why did you get that kind of achievement?
4. As a past student, what would you consider to be most impressive learning experiences of science you ever encountered? Why?
5. As a practicing teacher, what would you consider to be the most impressive teaching experiences of science ever? Why?
6. Based on your teaching experiences, what is the most effective way for you and your students to teach and learn science respectively?
7. In your current role as a science teacher, tell what do you consider to be the effect of the education reform on the teaching and learning of science?
8. What challenges do you experience teaching science in with a manner consistent with the education reform?

Second interview (conceptions of science*)

1. According to your understanding, what is science?
2. How do we or scientists acquire scientific knowledge?
3. What are key characteristics of scientific knowledge?
   3.1. How are law and theory different from the other?
4. How are science, technology, and society related to each other?
5. For what reasons should students learn science?

* The interview items are adapted from Promkatkeaw, Sungong, and Kaewviyudth (2007).

Appendix B

Interview Items

Interview about perceptions of teacher learning

Date: ____________

Name: _____________________________

Interviewer: _________________________

Interview context:

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1. As we have been engaging in group discussion, could you describe what you have learned during this kind of activity?
   1.1. Is that helpful to improve your teaching practices? How?
2. What kind of difficulty or challenge have you experienced when you attempt to improve your teaching practice?
3. What part of your teaching practices do you think that should be improved in the near future? How would you do?
4. What would you want to suggest about the use of this kind of teacher development approach in schools?

BIOGRAPHICAL DATA

Name – Surname	Mr. LUECHA LADACHART
Date of Birth	November 8, 1979
Place of Birth	Trang, Thailand
Education	2002, Prince of Songkla University, Grad.Dip. (Teaching Science Profession) 2001, Prince of Songkla University, B.Sc. (Physics)
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
Scholarships	The scholarship to pursue Ph.D. (Science Education) from the Institute for the Promotion of Teaching Science and Technology (IPST), Thailand The scholarship for research funding from the Graduate School, Kasetsart University, Thailand