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Investigating the Shifts in Thai Teachers' Views of Learning and Pedagogical Practices While Adopting an Argument-Based Inquiry Approach

Nattida Promyod
University of Iowa

INVESTIGATING THE SHIFTS IN THAI TEACHERS' VIEWS OF LEARNING AND PEDAGOGICAL PRACTICES WHILE ADOPTING AN ARGUMENT-BASED INQUIRY APPROACH

by

Nattida Promyod

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Thesis Supervisor: Professor Brian Hand

Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

PH.D. THESIS

This is to certify that the Ph.D. thesis of

Nattida Promyod

has been approved by the Examining Committee
for the thesis requirement for the Doctor of Philosophy
degree in Science Education at the August 2013 graduation.

Thesis Committee: ___________________________
Brian Hand, Thesis Supervisor

____
Soonhye Park

____
Cory T. Forbes

____
Walter Vispoel

____
Charles T. Foster

I dedicate this dissertation to
my mom and dad for their unconditional love and endless support.
I love you dearly.

Do not be afraid of trying something new. It is good for our students, indeed. My students are now more confident sharing their ideas. This makes me, as their teacher, very proud and happy.

Teacher Kamonwan (Pseudonym)
Taken from the Reflection Interview
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ABSTRACT

The purpose of this study was to investigate the shift of Thai teachers' views of learning and their pedagogical practices from the traditional approach to be more centered on an argument-based inquiry approach (ABI) in Thai classrooms, where teachers and learners have long been familiar with the lecture-based tradition. Other than examining the changes, the study further explored the relationship throughout the ABI implementation phase with a specific focus on driving questions, problem solving and reasoning, and establishing a supportive learning environment.

The study was conducted in Thailand with five physics teachers. Data collection involved classroom observations and teacher interviews. The constant comparative method was employed throughout the data analysis process. The research questions that guided this study were: (1) What changes occurred in teachers' pedagogical practices and views of learning throughout the implementation phase of the argument-based inquiry approach? (2) If change did occur, what was the relationship of the change among the observed criteria (questioning, problem solving, and the establishing of a supportive learning environment)?

The results revealed that after fourteen weeks, the three teachers who expressed a positive attitude toward the ABI approach and expressed their willingness to practice started to shift their practices and views of learning toward a student-centered model. Although each teacher exhibited a different starting point within the three observed criteria, they all began to shift their practices first, before reflecting on their beliefs. In contrast to these teachers, the other two teachers were impeded by several barriers and therefore failed to implement the approach. These positive attitude, willingness, and shift of practice appear to be connected and necessary for change.

The study highlights that in order to support the implementation of the ABI approach, especially in a large class size cultural setting, opportunities for teachers to be

challenged in both classroom and cognitive spaces, where they are immersed in authentic practices and be able to reflect on their own actions as well as their existing beliefs, are crucial. However, to advance the dimensions of this issue, long-term professional development and a longitudinal study observing a large class size cultural settings are suggested.

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CHAPTER 1

INTRODUCTION

Inquiry-based science learning has had a long history of development (Barrow, 2006; Anderson, 2002). In its publication of the National Science Education Standards (NSES) in 1996, the National Research Council (NRC) declared that scientific inquiry is central to science learning, and emphasized the importance of the active learning process. The NRC further stated that student performance needs to be better aligned with the inquiry-based approach; students need to be able to ask scientific questions, conduct investigations, think critically, and explain phenomena in the natural world. It was to this end that the idea of improving science literacy was highlighted in the NSES. Furthermore, the NRC emphasized that young learners need to be able to apply their scientific knowledge and inquiry skills when making decisions, and are expected to be competent when participating in public discourse. Importantly, students need to be familiar with the skills of scientific argumentation in order to communicate with others in the scientific community (NRC, 1996).

In the past, science learning was primarily seen as a process in which learners absorbed knowledge (Bybee et al., 2006). Teachers were particularly significant in this process as they drove all classroom activities and essentially functioned as information providers. However, recently new learning research has pointed to the value of classroom activities based on the concepts of cognitive learning theory. During such activities, individuals are actively involved in the process of knowledge construction as they integrate new experiences into their existing knowledge through social interactions (Driver & Oldham, 1986; Henrique, 1997; Coleman, Perry, & Schwen, 1997; Fahy, 2004).

Therefore, while didactic teaching predominated in the past, we are now seeing a shift away from teacher-directed learning toward a student-centered orientation (NRC, 1996). To facilitate this change, we need to better understand teachers' views of learning, how learning takes place, how a science classroom can be a supportive resource to purposefully drive the inquiry process, and what barriers teachers encounter during the implementation of the new approach. Furthermore, even though activities based in cognitive learning theory are effective promoters of critical thinking and active learning, their effectiveness is limited if teachers retain a traditional view of learning (Wallace & Kang, 2004; Kelly & Staver, 2005; Roehrig & Kruse, 2005). Such teachers tend to align their practices with a teacher-directed style (Bandura, 1986).

In addition, science teachers do not show a consistent understanding of the meaning of inquiry-based learning and how to effectively implement this strategy in a science classroom (Marshall, Smart, & Horton, 2009; Marshall, Horton, Igo, & Switzer, 2009). Thus, many researchers have indicated that inquiry is not always successfully implemented in classrooms as expected (Crawford, 2007; Bybee, 2000). Accordingly, developing teachers' views of learning becomes an important part of the implementation phase of new curricula (Cronin-Jones, 1991).

Another aspect of cognitive learning theory that is incorporated into inquiry-based learning is the importance of argument-based inquiry, in which learners are encouraged to be active participants who construct knowledge through investigation and negotiation. Under the inquiry-based science learning schema, children are offered the authority to think and drive their learning tasks (Prawat, 1992; Hand, 2008). The Science Writing Heuristic (SWH) approach (Hand, Wallace, & Yang, 2004), which is an argument-based inquiry approach based on the constructivist view of learning, is used to help teachers implement argument-based inquiry in their science classrooms. This approach promotes students' reasoning skills and encourages them to develop their ideas through a negotiation process. The SWH teacher template guides teachers through the processes of argumentative practice and shapes their views of learning toward the constructivist perspective. Teachers are encouraged to use high-order questions to promote students' critical thinking and problem solving skills, and they are also shown how to create a non-threatening learning environment that can support student ownership of learning and social interaction. Teacher voice is no longer the main feature of the classroom (Norton-Meier, Hand, Hockenberry, & Wise, 2008). Therefore, the SWH approach allows teachers to shift their views of learning as well as their practices toward argument-based inquiry learning orientations.

Science Education in Thailand

In Thailand's educational system, the Thai government generally provides opportunities for all children to receive an equal right for a free 12 years basic education including 6 years of primary education, 3 years of lower secondary education, and 3 years of upper secondary education. The compulsory education requires that all 7-year-olds students enroll in basic education from primary school to lower secondary education (Office of the Education Council, 2004).

In general, the Thai national curriculum is categorized into 8 groups of subjects: Thai Language; Mathematics; Science; Social Studies; Religion and Culture; Health Education and Physical Education; Art; Career and Technology-Related Education; and Foreign Language. In terms of learning assessment, students in grades 3, 6, 9, and 12 are required to take the national tests, which aim to evaluate and monitor students' achievement and the educational quality at different levels (The Institute for the Promotion of Teaching Science and Technology [IPST], 2008). At the higher education level, the admission system recently requires students' GPA and national test scores consisting of the Ordinary National Educational Test (O-NET) and the Advanced National Educational Test (A-NET).

As stated in the *National Science Curriculum Standards: The Basic Education Curriculum B.E. 2551* (IPST, 2008), learning science in Thailand focuses on eight areas which purposefully promote learners to socially connect their classroom knowledge to their daily life skills. These areas of focus include: 1) living things and processes of life; 2) life and the environment; 3) substances and properties of substances; 4) forces and motion; 5) energy; 6) changing processes of the earth; 7) astronomy and space; and 8) nature of science and technology. Subject areas advance from simple to more complex contents in ascending grade levels (Soydhurum, 2001).

As illustrated in table 1-1, science curricular in Thailand is different in each school level (Soydhurum, 2001, p. 27).

Table 1-1 Science Curricular for Each School Level in Thailand

Level	*Stream*	*Science Curriculum*
Primary	-	Integrated into "Life Experiences" subject group
Lower secondary	-	General science
Upper secondary	Academic • Science program	• Physics, Chemistry, Biology • Environmental Science
	• Non-science program	• Physical Science • Environmental Science
	Vocational	• Fundamental Science for professional courses

Generally, the lower secondary level requires students to complete 9 credits of science, which is 3 periods per week. The upper secondary education students must have 240 hours or 6 credits of core subjects, which is 3-4 periods/week/subject of 1.5-2 credits.

The Nation Education Act of 1999 (Sriphan, 2002) outlined that investigation, problem solving, and knowledge construction are skills that aim at the heart of the educational reform in order to enable learners to be competent in science learning. In accordance with this emphasis, student-centered orientation has become central to science education reform in Thailand. IPST, under the Ministry of Education which takes responsibility for developing the National Curriculum in science teaching for grades K-12. This curriculum is composed of core requirements and learning standards. However, schools are free to decide their own curriculum based on the national science curriculum (IPST, 2008). In addition, they can either use textbooks developed by the government or other private corporations.

Statement of Problem

This study was conducted in Thailand, where teachers and learners have long been familiar with the lecture-based tradition (Buarapha, Singh, & Roadrangka, 2006). Previous research of other Asian countries has shown that implementing an unfamiliar inquiry-based learning approach has proven difficult because their science classrooms have been typically set up with the teacher as information deliverer and the student as passive observer (Choi, Nam, & Seung, 2011). In Thailand, even though an official push toward the student-centered learning approach has been ongoing for some years (Office of the Education Council [OEC], 2004), many teachers still function as traditional instructors; they act as lecturers and knowledge transmitters. Furthermore, Puengpang, Roadrangka, and Cowie (2007) indicated that Thai science teachers still lack an understanding of content knowledge, pedagogical content knowledge, and analytical and critical thinking skills.

In the secondary education level, a large class size makes it difficult for teachers to handle and supervise students' learning activities. In addition, the administrators interest in students' achievement in university entrance examinations; as a result, it is difficult for teachers to promote "positive attitude towards science in the students and development of their science process skills through practical experience" (Soydhurum, 2001, p. 15). Hence, Thai learners have been generally taught to be passive (Narjaikaew, Emarat, & Cowie, 2009; Soankwan, Emarat, Arayathanikul, & Chitaree, 2007). In terms of learning assessment, rather than paying attention to students' scientific process, problem solving skills, and scientific attitude, rote learning resides in the basic assessments. As a result, many Thai students spent time on tutoring classes to prepare themselves for university admission (Soydhurum, 2001). The results from Thai national test on learning achievement reveal that the upper secondary students' average score in science is below fifty percent; furthermore, international examinations such as TIMSS and PISA have continuously shown that Thai students perform poorly in science and mathematics (Soydhurum, 2001).

Buarapha and colleagues (2006) studied the teaching of a Force and Motion unit in a Thai secondary classroom and in a physics methods course at a university. They concluded that the teachers were basically acting as lecturers – little effort was made on the part of teachers to encourage the learners to understand key concepts and to apply the content to real life. The researchers mentioned that this type of learning left students unenthusiastic about physics and physics study. Furthermore, Soankwan and his colleagues (2007) revealed that Thai students, like other students around the world, think of physics as a difficult subject. Many physics teachers still simply lecture, and hence, students inevitably learn the subject by rote learning and by following their teachers' instructions (Buarapha et al., 2006). As a result, students lack interest in learning physics and possess little self-motivation when learning the subject simply to meet curriculum requirements rather than in order to appreciate its values (Buarapha et al., 2006). After noting the depth of this problem, Soankwan and his colleagues (2007) suggested that new ways of changing teachers' views and practices were needed if the aims of Thailand's student-centered reformed education were to be met. One of the core items in the new science teaching system (OEC, 2004) was that Thai students were to learn physics with understanding, and for that to happen, a change in teachers' views and practices was clearly necessary.

The Significance of the Study

Research into teachers' beliefs, values, and understanding of the learning process is important as it is related to and can reveal much about their instructional practices (Leatham, 2006). As documented in several studies, the issue of teachers' views of learning in relation to their practices is particularly noteworthy when teachers consider adopting a new teaching practice in their classroom (Tobin & LaMaster, 1995; Yerrick, Park, & Nugent, 1997). However, most research studies concerned with changing teachers' learning perspectives and classroom practices have been conducted in the United States; research in the Asian context is rare. This study is significant in that it aimed to fill that gap. Thus, this study investigated the shift in Thai teachers' learning perspectives and classroom practices as they facilitated a reformed science-teaching program.

Argument-based inquiry benefits young learners by developing their conceptual understanding and their ability to actively defend their positions through robust interaction with peers and teachers. The process also develops their critical thinking skills and knowledge base (Hand, 2008). Furthermore, argument-based inquiry leads not only to improved student cognitive and social skills, but also to better understanding of epistemological scientific knowledge (Newman, Driver, & Osborne, 1999; Driver, Newton, & Osborne, 2000; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Duschl, 2008). Despite the fact that a number of studies have affirmed the benefits of the approach, there are only a small number of schools internationally that provide the opportunity for learners to actively construct and develop their own arguments (Driver et al., 2000). Few teachers at the high school level emphasize the idea of cognitive inquiry skills in their teaching. It also seems to be the case that high school students do not possess the skills to construct their own knowledge because their learning to date has not been engaged with and connected to their real life experiences (Goodrum, Hackling, & Rennie, 2001).

In addition to the research trends mentioned above, the majority of the studies to date have focused on the shift of perspectives and practices found in preservice teachers (Martin & Hand, 2009). Few studies attempt to elucidate this shift in experienced high school teachers, and especially in physics teachers. Thus, this study was centered on inservice teachers at the high school level, and the aim of this study was an in-depth investigation of teachers' learning perspectives, classroom practices, and concerns as the teachers run a reformed science program. According to Vaughan (2002), teachers' concerns impact their comfort level with participation. Thus, the issue of teachers' concerns, particularly during a period of change or innovation, was also significant.

In terms of classroom practices, this study focused on teachers' questioning, problem solving and reasoning, and establishment of a supportive learning environment throughout the argument-based inquiry implementation process. These three aspects were chosen because they were critical components of the argument-based inquiry approach. Scientifically-oriented questioning is considered a powerful tool that can stimulate learners to think critically, and it is fundamental to inquiry learning (Oliveira, 2010; NRC, 2000, 2012). Therefore, the role of scientifically-oriented questions becomes significant because they strengthen learners' abilities to think critically, inspire them to design their own investigations, and lead them to purposefully negotiate their work with others in the public domain (Bell, Smetana, & Binns, 2005). However, research has shown that there is still insufficient use of effective questioning in the classroom (Downing & Gifford, 1996), especially so for questioning that scaffolds the inquiry learning process (Martin & Hand, 2009; Weiss & Pasley, 2004; Carlsen, 1997).

Problem solving and reasoning is one of the emphasized essential characteristics for learners in an inquiry classroom (NRC, 2000; American Association for the

Advancement of Science [AAAS], 1993). Engaging students in an authentic problem solving activity is important for developing their critical thinking and reasoning skills (Chiappetta, 1997; Gillies & Khan, 2008). In addition, problem-solving activities encourage and engage students with knowledge construction and the processing of social interactions (Polman, 2004; Duschl, 2003).

The importance of teachers establishing a supportive learning environment seems clear. When they do so, the quality of student learning increases because they are engaged and motivated throughout the lesson (Darby, 2005). Thus, an appropriate learning environment is a key factor in meeting the goals of an argument-based inquiry classroom (Hand, 2008). However, Flick (1995) noted a lack of research focused on how teachers build an environment to promote students' cognitive learning and social interactions. To signal the change toward an argument-based inquiry approach, a transformation of classroom environment is another important factor.

This study therefore addressed a gap in the literature by providing a deep and helpful description of the change in teacher pedagogical practices and views of learning associated with the argument-based inquiry approach. Further, this study emphasized effective questioning, problem solving and reasoning, and the establishment of a supportive learning environment, all three of which are insufficiently treated in science education research studies. These three aspects were used to track the ongoing change or realignment process that occurred throughout the semester of observation. Such findings, as well as findings related to barriers that teachers faced, provide implications for future research studies and further implementation of argument-based inquiry in the larger context of Thai education.

Purpose of the Study

As stated in several studies, teachers' views are closely related to their implementation of new teaching approaches and the way they solve problems (Harteis, Gruber, & Lehner, 2006; Tsai, 2001; Ghaith & Yaghi, 1997). Before the argument-based inquiry approach can be successfully employed in Thai classrooms, processes by which teachers' practices and views of learning shift should be understood.

A major point of interest in this study was to determine how argument-based inquiry is effective in Thailand. To begin this process, it is necessary to understand what views teachers hold, how they can shift their ideas, and what concerns they have during the implementation of the new approach. According to studies conducted in the United States, teachers are able to shift their views of learning toward a student-centered approach. However, Cavagnetto (2008) mentioned in his study that it took time for teachers to implement the Science Writing Heuristic (SWH) approach in their classrooms. In addition, other researchers investigated the implementation of an innovative learning approach stated that it would take from eighteen months to three years for teachers to significantly shift their practices or begin to fully understand the new approach and its orientation toward learning (Martin & Hand, 2009; Blumenfeld, Krajcik, Marx, & Soloway, 1994). Because this study was conducted over fourteen week period, there was not an expectation for substantial change in teachers' views of learning and practices. However, the emphasis of this study was on the change of teachers' views of learning and their practices at the beginning of the implementation process of the argument-based inquiry approach.

Accordingly, the purpose of this study was to investigate how teachers shifted their practices and their views of learning when implementing an argument-based inquiry approach through a specific focus on their views concerning the role of driving questions, problem solving and reasoning, and their establishment of a supportive learning environment. Progress in these areas was tracked by examining the change or realignment of teachers' views about learning and their practices, as well as the relationship among the observed criteria during the implementation process. In this light, the type, level, and quality of teachers' questions were crucial in promoting students' higher-order thinking, argumentation discourse, and problem solving skills. In addition, how learners were engaged in inquiry activities and encouraging learning environments were crucial. Furthermore, the study aimed to examine teachers' concerns or barriers that they experienced as they implemented the reformed strategy.

Research Questions

The research questions that guided this study were focused on the change in teachers' views of learning and their teaching practices:

1. What changes occurred in teachers' pedagogical practices and views of learning throughout the implementation phase of the argument-based inquiry approach?
2. If change did occur, what was the relationship of the change among the observed criteria (questioning, problem solving, and the establishing of a supportive learning environment)?

Overview of the Study

This research study is divided into five chapters. Chapter One is an overview of the study that includes the research rationale, context of science education in Thailand, statement of problem, significance of the study, purpose of the study, and research questions.

Chapter Two provides three theoretical frameworks that guided the study: (1) the constructivist view of learning and the theory of conceptual change; (2) the shift of teachers' views of learning and their teaching practices; and (3) factors that promote and prevent teachers from implementing argument-based inquiry in a science classroom. In addition, this chapter reviews the relevant literatures on the shifts in teachers' views and practices in relationship to argument-based inquiry and its critical elements, including learning, language, and negotiation. Finally, the chapter touches upon the three observed criteria in this study: (1) questioning, (2) problem solving and reasoning, and (3) learning environment.

Chapter Three focuses on: the methodology framework; research design; data collection; and analysis procedure. The end of the chapter also justifies the trustworthiness of the study.

Chapter Four includes the findings of the study regarding the shift in teachers' views of learning and pedagogical practices based on the three observed criteria.

Chapter Five is a discussion of the findings in relation to the research questions. The main emergent themes of this study are discussed. In addition, the study's limitations and implications for future research are provided.

CHAPTER 2

LITURATURE REVIEW

This chapter focuses on the literature related to the theoretical framework of this study including: a) constructivist views of learning and conceptual change; b) the shift of teachers' beliefs and practices; and c) factors that promote and prevent teachers' adoption of the argument-based inquiry approach in science classrooms. In addition, the chapter discusses the relevant literatures involving: a) argument-based inquiry; b) learning, language, and negotiation as the critical elements of argument-based inquiry; and c) questioning, problem solving and reasoning, and the establishment of a supportive learning environment as keys to enhancing argument-based inquiry learning.

Theoretical Framework of the Study

In the last two decades, the perspective of science education has been that students should construct their own knowledge and become active participants in their learning (Anderson, 2002; Weiss, Pasley, Smith, Banilower, & Heck, 2003; Portes & Ochs, 2003; Barrow, 2006; Haney & McArthur, 2002). Currently, the theoretical model of learning is framed around cognitive growth and the adoption of a constructivist version of the world; supporting this type of learning in the classroom means that teachers need to undergo a conceptual change from traditional models of teaching to a student-directed view of learning.

Constructivist Learning Theory and Conceptual Change

Based on cognitive learning theory, the constructivist view of learning emphasizes a student-centered orientation (Hand, Treagust, & Vance, 1997). This strategy considers that learners can construct their own knowledge (Henriques, 1997), and that knowledge is constructed by individuals though social interactions (Henriques, 1997; Simon, 1995; Berland & Reiser, 2009; Newman et al., 1999; Driver et al., 2000;

Driver et al., 1994). As explained by Piaget's theory of learning, knowledge is constructed at the private level when a person reflects on and makes sense of social interactions with the natural world (Henriques, 1997; Bybee et al., 2006; Driver & Oldham, 1986). Constructivist learning theory then explains how people learn from and make sense of the meaning of the world (Henriques, 1997; Simon, 1995).

Seen from the constructivist perspective, teaching is a process that encourages students to construct their own scientific knowledge based on their individual experiences and their dialogical interactions in their environment (Jonassen, 1999; Vrasidas, 2000). Previous studies have highlighted that scientific understanding is not only individually but also socially constructed (Driver et al., 1994; Driver et al., 2000). To be efficient participants in a scientific community, learners need to be able to express their own explanations in a way that meaningfully situates them in a social setting, supported by evidence taken from investigations (NRC, 1996).

As mentioned previously, knowledge is constructed as a result of individual and social components. Through social interaction (public aspect), this process triggers and challenges learners to reflect on their existing knowledge. Doing this, in turn, means that learners construct the meaning of the phenomena in a way that makes sense to themselves (private aspect). Thus, the private aspect refers to the attempt of an individual to create meaning from phenomena or to make sense of such interactions (Henriques, 1997; Windschitl, 2002). Language is a tool that learners use to represent and communicate their thoughts to others; the process of negotiation plays a role in this for making meaning of phenomena (Lemke, 1995; Norris & Phillip, 2003; Yore, 2004). Cobb, Yackel, and Wood (1992) presented the idea of "taken-as-shared" to explain how individual knowledge is expressed and exchanged in society. According to the concept of science as a social enterprise, new scientific knowledge is not accepted publicly until the claims are criticized or scrutinized by a community of scientists. So in effect, students prepare for this reality as they argue and negotiate with their classmates. Thus, the core of the constructivist view of learning is to support a learning environment where students gain opportunities to build their understanding of the world through active investigations (Hand, 2008).

As explained in Chapter 1, traditionally the Thai educational system has been based on a process of information transfer. To shift Thai teachers' views of learning and teaching practices to a constructivist pedagogical model, therefore, requires a conceptual change. Henriques (1997) stated that knowledge is constructed by learners as a result of social interactions in the physical world and the integration of these experiences with an individual's prior knowledge. Along these lines, Shymansky and colleagues (1993) explained:

> Constructivists recognize the role of assimilation, accommodation and disequilibrium but place greater emphasis on the role of prior context-specific knowledge than would more Piagetian advocates. These prior knowledge structures, constructivists explain, act as both filters and facilitators of new ideas and experiences and themselves may become transformed during learning. (p. 740: cited in Henriques, 1997)

Shifting views of learning and teaching practices to a more student-centered approach is related to conceptual change theory (Posner, Strike, Hewson, & Gertzog, 1982; Duit & Treagust, 2003), which explains that people have their own mental schema about the natural world. To promote disequilibrium, they have to be challenged to be dissatisfied with their existing framework. When individuals have an opportunity to explore and investigate the world, they use their experience or existing knowledge to work on a problem until they are dissatisfied with that existing knowledge due to their real world exploration. This creates the potential for a new concept to replace the old idea if the new one, when tested, makes more sense than the old. For example, teachers may not accept or agree to implement a reformed curriculum until they see that it really works to improve student learning (Guskey, 2002). For individuals to learn about and adopt a new idea, the new concept should be intelligible, plausible, and fruitful in the context of their investigations. Through this process, the new idea has the potential to be assimilated into, or accommodated by, their mental framework (Posner et al., 1982).

Both cognitive and practice spaces are critical epistemic practices for promoting conceptual change in science (Sandoval & Milwood, 2005; Schwarz, 2009; Ford, 2008). It follows, therefore, that teachers should be offered opportunities to work on different problems to test and ensure that a new concept is also workable with the new problem (Posner et al., 1982). As a whole, teachers construct or interpret the meaning of the world from their own teaching experience, and the inquiry process triggers their curiosity and eagerness to explore the natural world (Bybee, 2002).

Ford (2008) explained, "Grasp of practice" as a tool of learning in both disciplinary authority and accountability. In this light, instead of factual understanding, the grasp of practice promotes students' deep understanding of concepts and scientific method. Thus, this approach emphasizes the role of knowledge construction and the role of critique through the process of making sense of a new scientific method. Hence, students would have opportunities for constructing authentic knowledge, understanding how to make sense of and value knowledge, learning where the knowledge comes from, and being able to integrate their prior knowledge with new ideas and to connect it to other situations.

Reflection is an important part of the conceptual change process in that it is an opportunity for learners to structure or reshape their understanding, ponder ideas, and identify their beliefs and practices (Bransford, 1999; Ford, 2008; Crawford, 1999; Bryan & Abell, 1999). Because science is a social enterprise, without cognitive reflection or critique in scientific practices, knowledge construction may not occur (Ford, 2008). Therefore, to promote a shift in teachers' practices and beliefs, it is necessary that they receive opportunities to reflect on and critique the essence of the new approach and to deliberate how to fit it into their classroom environments (Ford, 2008).

The Shift of Teachers' Views of Learning and Pedagogical Practices through a New Learning Approach

Individual belief systems are complex (Boulton-Lewis, Smith, McCrindle, Burnett, & Campbell, 2001; Bryan, 2003; Crawford, 2007; Peterson, Fennema, Carpenter, & Loef, 1989; Wallace & Kang, 2004). As highlighted in several studies, people's beliefs appear to drive their actions. In other words, beliefs and practices are interrelated, and beliefs are trustworthy indicators of the decisions people have the potential to make (Bandura, 1986; Nespor, 1987; Pajares, 1992; Luft & Roehrig, 2007; Kang & Wallace, 2004; Roehring & Luft, 2004; Czerniak & Lumpe, 1996). In the same way, teachers' beliefs about scientific learning play an important role in shaping their practices in the classroom (Boulton-Lewis et al., 2001; Haney, Lumpe, Czerniak, & Egan, 2002; Luft, Roehrig, & Patterson, 2003; Richardson, Anders, Tidwell, & Lloyd, 1991; Yerrick et al., 1997; Anderson, 2002).

Pajares (1992) and Nespor (1987) indicated that belief is a level of thought that explains the cognitive process and relates to people's perceptions. Along these lines, teachers' values and beliefs about teaching and learning are likely to guide their teaching practices (Pajares, 1992; Bryan, 2003). Teachers' beliefs also influence their interpretation of pedagogical strategies, which sometimes may or may not align with how those concepts are presented in literature (Borko & Putman, 1995; van Driel, Beijaard, & Verloop, 2001; Yerrick et al., 1997). For example, a teacher may infer an inquiry activity as a hands-on activity in which students follow the teacher's instructions and do not discuss with each other what they are doing; in contrast, a teacher who interprets an inquiry activity as a way to engage students in social interaction will promote them to come up with their own explanations to describe the phenomena they are investigating (Rankin, 2000; Crawford, 2000).

Some researchers have suggested that beliefs that are in conflict with the knowledge teachers have learned in college or with a curriculum's intended meaning may cause teachers to struggle to successfully implement reformed teaching approaches (Kelly & Staver, 2005; Roehrig & Kruse, 2005; Wallace & Kang, 2004). In this case, beliefs and knowledge are not the same, even though their definitions sometimes overlap and interplay (Bryan & Abell, 1999). To clarify, knowledge is actually defined as a factual and rational idea based on facts and experiments (Gess-Newsome, 1999), whereas belief is defined as an emotional component arising from people's experiences, attitudes, and values (Richardson, 1996; Bryan, 2003; Gee-Newsome, 1999). Several studies have shown that beliefs play a greater role than knowledge in determining teachers' practices (Bryan, 2003; Kagan, 1990; Leatham, 2006; Nespor, 1987). Hence, to shift teachers' practices to a constructivist learning approach, determining their attitudes, perceptions, values, and beliefs should be the main focus (Richardson, 1998; Martin & Hand, 2009; Ghaith & Yaghi, 1997). In this study, the researcher realized that teachers' beliefs and knowledge are complex and interplay (Crawford, 2007; Bryan & Abell, 1999). Thus, this study employed the word, "views," to reflect and describe teachers' opinions about learning that might come from their beliefs, knowledge, or the interaction between both.

An argument-based inquiry approach might well use textbooks far less than a traditional approach, as students rather than textbooks are now the main resource at the center of learning (Ballone Duran, McArthur, & Van Hook, 2004; Simon, Erduran, & Osborne, 2006; Fetters, Czerniak, Fish, & Shawberry, 2002). Thus, the shift from a traditional classroom to an argument-based classroom requires a change in both the activities and resources used (Simon et al., 2006). To successfully implement argumentation, teachers have to change their actions; this process requires them to shift their learning orientation towards cognitive theory as it impacts their pedagogical practices (Dexter, Anderson, & Becker, 1999; Wetzel, 2001; Schwarz, Neuman, Gil, & Ilya, 2003). Volkmann and Abell (2003) likened this process to that of modifying a "cookbook," suggesting that teachers need to change their direct instructions into an inquiry investigation where students are encouraged to figure out their own procedure for the problems and develop their own explanations.

However, the way and direction in which teachers' beliefs and practices shift is complicated and varies situation by situation. To illustrate, Luft (2001) identified that novice teachers often first begin with shifting their beliefs, while experienced teachers seem first to change their classroom practices. Shifting pedagogical practices does not always begin with shifting beliefs because inquiry teaching can also shape teachers' understanding of scientific inquiry learning. For example, many teachers may begin by trying a new curriculum and then may change or think about changing their beliefs when they find the new approach works to promote positive outcomes in their students (Anderson, 2002; Simmon et al., 1999; Guskey, 1986; Huberman & Miles, 1984; Arora, Kean, & Anthony, 2000; Hand & Treagust, 1997). Alternatively, sometimes teachers shape new beliefs about practice due to the barriers they encounter. For example, even though some teachers might initially believe in the effectiveness of the concept of student-centered learning, the dilemmas they confront in their particular school circumstances may transform their beliefs to become congruent with more teacher-centered practices (Simmons et al., 1999).

Research studies of the relationship between teachers' beliefs and actions show both consistent and inconsistent practices. For example, numerous studies have suggested that sometimes teachers change their beliefs but do not develop their practices (Simmons et al., 1991; Luft, 2001). For instance, many teachers believe in the student-directed approach but still continue to use traditional instruction methods (Kang & Wallace, 2005; Simmons et al., 1999). Some teachers align their practices with their beliefs, even if this conflicts with what they have been taught (Ertmer, 2005). There are also teachers who simultaneously hold both old and new ideas about teaching; their learning and actions mix and change depending on the situation and personal factors (Bryan, 2003; Hancock & Gallard, 2004; Marx, Blumenfeld, Krajcik, & Soloway, 1997). Such factors include teaching goals, the types of students, and their classroom environments. In cases like these, teachers' beliefs sometimes show an inconsistent relationship to practices (Kang & Wallace, 2005; Tobin, Tippins, & Gallard, 1993). These studies suggest that shifting teachers' views to constructivist learning does not necessarily mean that their empirical teaching behavior will undergo a similar shift (Duit & Treagust, 2003; Fischler, 1994).

Crawford (2000) indicated that teachers who emphasize the 'one right answer' approach find it difficult to run argumentative discourse classrooms where students are free to negotiate their ideas without the fear of presenting 'wrong answers.' In terms of implementing argument-based inquiry, if teachers shift their classroom pattern from teacher-centered to student-centered, the goal of science learning should be permanently changed from focusing on 'content' to 'concept' or 'big idea' (Hand, 2008). In addition, language is a critical element of argumentation (Lemke, 1999; Mortimer & Scott, 2003). However, Lemke (1999) argued that it is difficult to shift teachers' views of learning from teacher-directed to a model that uses scientific language for knowledge construction. Working through this process, teachers need to understand how to use language as a learning tool to communicate and negotiate ideas, and they also must comprehend its role in terms of structuring scientific knowledge in the community (Windschitl, 2002).

Factors that Promote and Prevent Teachers from Implementing Argument-based Inquiry in Science Classrooms

Even though several studies reveal that beliefs guide teachers' practices, other research suggests that due to various factors, teachers' beliefs may not direct their teaching behaviors (Tobin, Tippins, & Gallard, 1993; Wetzel, 2001; Prawat, 1992). When challenging teachers to implement a new curriculum, it appears that some attempts at setting up inquiry-based classes have not been successful because of poor understanding of the concept of inquiry-based learning (Anderson, 2007; Wilson, Taylor, Kowalski, & Carlson, 2010), which makes it difficult for teachers to shift their practices (Hewson, 2007; Duffy & Roehler, 1986). For instance, many teachers are still puzzled about the meaning and essence of inquiry, which causes them to struggle to adopt the approach in their classrooms (Crawford, 2000; Anderson, 2002). Some teachers equate inquiry with hands-on activities, but this is not necessarily helpful since inquiry can take many forms, and not all hands-on activities involve inquiry (Rankin, 2000; Crawford, 1999). As many teachers do not understand inquiry learning well, it is not surprising that they cannot implement it (Crawford, 2000).

Davis, Petish, and Smithey (2006) stated that it is essential that teachers clearly understand the nature of inquiry and know how to align their activities to the inquiry approach. As noted, many challenges can occur during the implementation phase of this process. To successfully adopt the inquiry approach, teachers need to have a thorough understanding of both the nature of the strategy and the way in which it is to be implemented (Davis et al., 2006). It follows from this that although classroom discourse is a good way of promoting student negotiation skills, the process does not work well if teachers do not truly understand the approach's essence and remain too authoritarian (Hand, 2008). Under such conditions, students do not feel that they have the power to create questions or conduct their own investigations, and that they lack the authority to voice their arguments publicly (Newman et al., 1999; Driver et al., 2000; Simon et al., 2006; Board on Science Education [BOSE], 2008). Thus, teachers have to understand that in the inquiry-oriented approach they are no longer lecturers or knowledge providers but rather are facilitators. Their primary task is to provide students with a supportive learning environment that allows them to construct knowledge by themselves through the use of open-ended questions that enhance investigation and the thought processes aligned with scientific discourse (NRC, 2000).

Weiss and Pasley (2004) suggested that teachers are concerned with three broad areas of knowledge, including subject matter, pedagogical knowledge, and curricular knowledge. All of these areas are associated with teachers' practices. The actions of students in the classroom are also a significant element that affects practice (Weiss & Pasley, 2004). Most students have a hard time constructing arguments, and they also find it difficult to come up with evidence to support their claims (Driver et al., 2000; Osborne, Erduran, & Simon, 2004; Kuhn, 1991). To effectively practice these skills, they need to learn about the nature of argument as well as its construction (Driver et al., 2000). These factors are of primary importance because they are directly linked to teacher planning of what and how to teach in the classroom (Gee-Newsome, 1999; Shulman, 1986).

Research indicates that both student deficiencies and teacher limitations can be barriers to the successful implementation of inquiry-based science classes (Crawford, 2000; Lederman & Niess, 2000). Anderson (2002, 1996) described the three major dilemmas that science teachers may encounter while they attempt to implement an inquiry-based learning approach. These include technical, political, and cultural dilemmas.

Technical dilemmas concern problems of content knowledge, pedagogy, assessing inquiry, designing lesson and class activities, and time management (Davis et al., 2006). Jackson (1968) provided an example of teachers who lacked conceptual understanding of reformed teaching; those teachers found it difficult to use scientific procedure to evaluate students' learning progression. Alberts (2000) claimed that teachers' knowledge of inquiry is another key technical dilemma, arguing that teachers who have never experienced teaching and learning science by inquiry may struggle to understand its essence and it is thus difficult for them to implement inquiry into their science classrooms. In other cases, sometimes teachers are willing to implement the reformed curriculum but do not have enough background knowledge to do so, or the new curriculum guidelines are not clear enough for them to restructure their teaching. Along these lines, several studies claim that due to a lack of clarity in the standards, many teachers are still confused about their role in inquiry learning (Anderson, 2002; Clough, 2002; Keys & Bryan, 2001; Lunetta, Hofstein, & Clough, 2007). Such factors can make the implementation of a new teaching concept very difficult.

Additionally, research indicates that a large barrier to the success of implementing argumentative discourse in classrooms is “limitation[s] in teachers’ pedagogical repertoires” (Newman et al., 1999, p. 553). The application of this new approach may increase teachers’ workloads and some have expressed concern about their ability to run the kind of class activities that come to the fore in this new style of class (Newman et al., 1999; Driver et al., 2000). Another factor that may well be a barrier to the adoption of argumentative discourse in the science classroom is time. Although many teachers realize the advantages of this approach, they point out that classroom discussions require a lot of time and that it would be impossible for them to manage to cover the entire syllabus were argumentative discourse to become more common in science classes (Newman et al., 1999; Yip, 2001).

Teaching goals are yet another technical dilemma that can affect the adoption of an argument-based inquiry approach. This difficulty occurs from teachers’ conflicting ideas about what and how to teach (Barrow, 2006). Some teachers align their teaching goals with simply completing a lesson plan, rather than with an attempt to meet the constructivist-learning goal of supporting students to construct their own knowledge (Crawford, 1999). When teachers concentrate too much on the subject matter of a lesson plan they tend to over-focus on content and to ignore students’ conceptual understanding. Therefore, it is necessary that teachers conduct their classes in a balanced manner. There is no doubt, of course, that they need to be clear on the content aims of the class, but they also need to have a clear understanding of how students learn. This has the greatest impact on how teachers design plans, how they act in the classroom, and how they will change their beliefs and practices (Tobin, 1987).

It is common for teachers to attempt to locate themselves in schools or districts that emphasize educational practices with which they are compatible (Cochran-Smith & Lytle, 1999). This leads to the issue of political dilemmas. In these cases, tensions result from dealing with the school, parental resistance, students' learning goals, and a lack of academic supports such as resources or limited professional development programs. For example, teachers who lack academic resources and learning materials have found it difficult to develop investigative activities or class discussion (McLaughlin, 1987; Kijkuakul, 2006). Such problems need to be dealt with carefully at the implementation stage. Educational policy, including curriculum and instructional policies, also affects the implementation of inquiry-based learning. Marchell and colleagues (2009) claimed that curriculum is an important variable affecting the type of instruction that occurs in a classroom.

Furthermore, school policy and parent involvement can impact the adoption of a new teaching approach (Hoover-Dempsey, Basslet, & Brissie, 1987), as do schooling and students' learning goals, which can influence whether a teacher decides to adopt science as inquiry (Crawford, 2007). At times teachers need to spend class time preparing students for competitive national exams; this is quite common in many Asian countries (Prawat, 1992). In these cases, even though teachers may want to implement a reformed teaching strategy like the inquiry-based approach, they are powerless to do so since the process requires too much time. Rather than spending time asking questions or letting students explore knowledge for themselves, their teaching style remains lecture-based and most of their class time is spent on tutoring students for the test. This difficulty impedes teachers' inquiry-based implementation (Ghaith & Yaghi, 1997).

Finally, cultural dilemmas, which Anderson (1996) asserts are the most significant factor to address for a successful transition process, have to do with challenges to beliefs and values about teaching and learning that occur due to the sudden change from a traditional to an inquiry-oriented teaching style (See also March & Simon, 1958).

Crawford (2007) argues that “a prospective teacher’s set of beliefs about pedagogy, school, students learning, and the nature of scientific inquiry may have been the overriding factors influencing choice and eventual success in teaching science as inquiry” (p.608). Although teachers have a responsibility to align their teaching with the curriculum, this does not mean that their beliefs can suddenly shift in line with new curriculum guidelines. Often they still try to respond to the policy in a way that makes sense to them or that is consistent with their existing knowledge, beliefs, and practices (Cohen & Ball, 1990). In this way, teachers will transform or modify the new policy or curriculum into a form with which they are comfortable or familiar.

Several studies have indicated that teachers’ confidence or self-efficacy influences their positive attitude toward teaching and willingness to convey their knowledge in the classroom, as well as their efforts to implement a new teaching approach (Bray-Clark & Bates, 2003; Guskey, 1988; Loughran, 1994; Ghaith & Yaghi, 1997; Miskel, McDonald, & Bloom, 1983). In fact, teachers who have high self-efficacy tend to improve their teaching by experimenting with more alternative knowledge and teaching strategies and are more tolerant to potential problems (Bray-Clark & Bates, 2003; Allinder, 1994; Haney, Czerniak, & Lumpe, 1996; Ross, 1994; Ghaith & Yaghi, 1997).

Ghaith and Yaghi (1997) indicated that teachers’ willingness to engage with a new teaching approach is a crucial factor during the implementation process. However, several factors influence this willingness, such as teachers’ past experiences (Banduara, 1977). As another example, many schools still insist that there is only one ‘right answer’ to problems (Driver et al., 2000). When teachers are too concerned with the ‘right answer,’ they may be unwilling or unable to really pay attention to and engage with students. Such a focus on lesson content may also indicate that a teacher does not understand how to encourage learning. It is noteworthy that in this situation, if the students offer no ‘right answer,’ the class is felt to be a failure. Such negative occurrences in the classroom not only reflect the way teachers assess student knowledge, but also mirror their teaching orientation.

In a reformed classroom, teacher and student attitudes toward learning significantly shape the success of the approach (Simon et al., 2006). To achieve argumentative discourse in schools, teachers need to be willing and able to abandon traditional ‘teacher-centered’ activities, and students need to adopt the roles of active open-minded thinkers and doers. However, changing people is difficult, as is changing their views about teaching and learning. It takes time for people to shift away from what they believe, even if that shift is to a new approach that has already been accepted by the experts. People need time to test, evaluate, and practice new ways of doing things and to discover what really makes sense to them (Posner et al., 1982).

In the case of Thai teachers, it would appear that many have not succeeded in implementing inquiry-based learning because of curriculum issues (Musikul, 2007). Even though Thai education has been pushed toward the student-centered model, the kinds of curricula that encourage the development of teachers’ beliefs appropriate to inquiry-based learning programs have not been developed, or when they have been developed, they have not been followed. One reason for this seems to be that teachers have lacked the necessary opportunities to practice the new styles required (Musikul, 2007). Another factor seems to have been insufficient professional development programs. Such training courses are necessary if teachers are to be equipped with the knowledge and skills needed to implement inquiry-based learning.

In conclusion, from the point of views of teachers, the argument-based learning approach is difficult since students are used to a didactic learning. It also seems that although argument is very much part of the furniture in the science community, not everyone thinks it is necessarily a ‘must’ in the science classroom (Newman et al., 1999; Simon, 2006; Driver et al., 2000). So it seems that the main obstacle to implementing and developing argument-based learning in the science classroom is a general lack of support for the idea of an argument-based environment in the classroom.

Although a number of research studies affirm the benefits of the approach to students, it appears that there are only a small number of schools that provide the opportunity for learners to actively construct and develop their own arguments (Driver et al., 2000). Teachers' concerns significantly affect their implementation of an innovative teaching strategy (Vaughan, 2002). Seemingly, it is not only students who have problems with implementing argument-based learning. It is of course teachers, as mentors, who play a significant role in the argumentative discourse classroom. Teachers need to understand the nature of argument and how to conduct, manage and push the class along to meet its goals. There are a lot of barriers facing both teachers who want to develop argument in their classroom, and students who want to learn via this new approach. However, its adoption seems well worthwhile when considering the exciting possibility of improved student learning outcomes.

Review of the Relevant Literatures

This literature review includes relevant studies regarding: argument-based inquiry; learning, language, and negotiation as the critical elements of argument-based inquiry; questioning, problem solving and reasoning, and the establishment of a supportive learning environment as keys to enhancing argument-based inquiry learning; and the Science Writing Heuristic (SWH) approach.

Argument-based Inquiry

Argument-based inquiry is an approach based on cognitive learning theory (Hand, 2008). Grounded in this theory, the argument-based inquiry approach is concerned with how people learn cognitively. In other words, it calls for active mental processes that feature learners as active participants, and it features negotiation in a key role as learners bring their own experiences into public (Hand, Norton-Meier, Staker, & Bintz, 2009).

Argument-based inquiry has been used in science learning as a tool to drive the scientific inquiry classroom in a way that enables all learners to communicate and reflect upon their reasoning by presenting claims and evidence to build new knowledge (Driver et al., 1994; NRC, 1996; Driver et al., 2000). Osborne, Erduran, and Simon (2004) stated that, "learning to think is learning to argue" (p. 998). According to their message, argument and learning go hand in hand. The argumentative approach encourages learners to be actively involved in oral and written class activities, and it promotes active participation. Simon, Erduran, and Osborne (2006) also claimed that "the teaching of argumentation through the use of appropriate activities and pedagogical strategies is a means of promoting epistemic, cognitive and social goals as well as enhancing students' conceptual understanding of science" (p.236).

There are a number of studies that focus on the use of argumentation in a science classroom, and these studies indicate that students develop their conceptual understanding through dialogical interactions with their teacher and peers. Therefore, the argument-based inquiry approach leads not only to students' improved cognitive and social skills, but also to their stronger understanding of the epistemology of scientific knowledge (Norman et al., 1999; Driver et al., 2000; Driver et al., 1994; Duschl, 2008; Cavagnetto, 2010). For argumentation to be successfully implemented in the science classroom, teachers need to understand from an epistemological perspective how scientific knowledge comes to have meaning and to comprehend the nature of argumentation in a science context (Driver et al., 1994; Osborne et al., 2004). Furthermore, they have to encourage students to actively talk and participate.

As argument-based inquiry is a process of negotiation and argumentation, students have to be immersed in and get actively involved through the processes of generating claims, building evidence, and negotiating their ideas with peers during engaging activities (Milar & Osborne, 1998; Siegel, 1995). Argument-based inquiry classrooms should effectively promote student abilities in the areas of knowledge construction, scientific modeling and practicing, questioning, problem solving and reasoning, the scientific method, the use of series of language, and socialization and communication skills. Overall, argument-based inquiry is very much concerned with the concepts of learning, negotiation, and the use of language as a learning tool.

Learning, Language, and Negotiation As the Critical Elements of Argument-based Inquiry

Learning

Learning by lecturing seems to be called 'doing school' rather than 'doing science' (Jimenez-Alexixandre, Rodriguez, & Duschl, 2000). Both terms represent totally different meanings. Jimenez-Alexixandre and colleagues (2000) presented their argument that 'doing school' is not aligned with the process of inquiry learning since it commonly requires students to complete a task by following teachers' instructions; as a result, there is no real scientific nature to the task, and little or no promotion of student understanding of the concepts behind an activity. Many teachers still employ a traditional teaching technique of encouraging students to learn from what is already done rather than motivating them to think about, make sense of, or construct the knowledge by themselves. Thus, it is important that teachers involve their students in learning how to 'do science,' rather than just 'doing school.'

Learning is an active inquiry process. In this light, students are expected to be able to demonstrate their ownership and work collaboratively with their peers as they build their own schema, and to communicate it to others through the negotiation process (Yager, 1991). In addition, learning is a product of the integration of students' existing ideas and the current things they are learning (Posner et al., 1982). As a result, learning is about negotiation as well as the process of conceptual change since learners have to negotiate and construct meaning from new ideas and their existing knowledge (Hand, 2008; Posner et al., 1982).

Defined by the NRC, the central goal of scientific teaching and learning is that "students [need to] learn scientific knowledge with understanding" (NRC, 1996, p.21). Learning without understanding is meaningless; students are expected to learn with understanding and then to be able to apply their knowledge to new or different contexts and negotiate it both privately and publicly across a variety of contexts and model forms (Hand, 2008). Students who have learned with understanding can apply or develop their knowledge and skills to new or different situations (Hand et al., 2009).

In the science inquiry classroom, students are expected to develop and construct knowledge by themselves (NRC, 1996). The students are the ones who do the thinking because if they stop thinking they stop learning (Hand, 2008). To do science as inquiry, then, students must become active participants in the learning process. Their role is shifted from passive receivers to active learners (Anderson, 2002). In this new role, memorizing information and absorbing knowledge from external sources such as teachers or textbooks does not seem to make sense. Instead, self-directed learning and the construction of knowledge based on conceptual understanding are desirable activities. When students take part in the inquiry process, they are potentially enthusiastic and desire to come up with multiple and new ways to investigate the natural world. Science as inquiry therefore encourages students to think like scientists (Duschl, 2008), improves their scientific ability, and promotes their learning by understanding (NRC, 2000). Theoretically, in order for students to succeed in their scientific argument-based inquiry efforts, it is important to enhance their cognitive and metacognitive processes by encouraging them to think critically as they solve problems, communicate, and publicly negotiate their ideas (Cavagnetto, 2010).

Negotiation

Through argumentative discourse, the construction of knowledge and skills becomes more than an individual process; in fact, the social negotiating processes that occur in the classroom lead to deeper and more meaningful knowledge construction (Driver et al., 1994; Driver & Oldham, 1986). As part of the shift towards the constructivist learning approach, negotiation is another significant innovative skill that teachers have to build up (Hand, 2008). Driver et al. (2000) explained that argument comes about in various stages. The first stage usually involves an individual who thinks and perhaps writes about the problem before searching for an explanation that makes sense. This process is in fact a kind of self-negotiation.

The second step involves that individual working on data prediction based on his or her own work. The third step is about group work; here another level of argument occurs which involves the individual yielding to the findings of the group. Next, the process reaches the upper levels of the scientific community. This might happen, for example, at a conference where members discuss the work. As the discussion proceeds, new knowledge emerges, and the individually constructed knowledge becomes public knowledge (Newman et al., 1999; Driver et al., 2000; Hand, 2008). The public presentation and defense of ideas and findings is a very important process in science learning since science is a social enterprise, and it is important that students see the link between participation in a scientific community and the growth of scientific ideas (Newman et al., 1999; Driver et al., 2000).

Claim and evidence are key components of argument and explanation (Hand, 2008), and being able to make a claim is a significant skill that students need to acquire. They should be able to articulate the claim and support it with appropriate evidence, and they should also be prepared to consider alternate explanations and theories. These skills are critical components involved in the construction of sound scientific arguments.

Having constructed a solid case, students may well then need to present their arguments to the public by way of social negotiation. In fact, it is often through talk and argument that students make their thinking visible (Driver et al., 2000; Driver et al., 1994; Osborne et al., 2004; BOSE, 2008). When people negotiate, they need to come up with relevant questions or problems, claims, and evidence to support their claims. The negotiating process facilitates on-going learning, as it demands that the participants think hard and get actively involved. If people stop negotiating, they stop thinking, and as highlighted above, when the thinking stops, learning stops. According to the concept of science as a social enterprise, new scientific knowledge is not accepted publicly until claims are criticized or scrutinized by a community of scientists. So in effect, students prepare for this reality as they argue and negotiate with their classmates. Ultimately, this argumentative practice leads students to improve their conceptual understanding and critical thinking skills (Driver et al., 2000; Hand, 2008; BOSE, 2008).

Even though negotiation is indeed a critical part of learning, many science classrooms do not implement or develop negotiation in classes. Too many teachers still see their role as authorities who pass down knowledge, and it is often only the 'right answer' that gets passed down. Thus, if we believe that negotiation is truly an integral part of learning, we need to make it happen much more frequently in science classrooms by encouraging students to explore and construct knowledge through the negotiation process.

Language

Language is also critically important to the practice of science, as well as being fundamentally important to advancing science learning (Bransford, Brown, & Cocking, 1999; Norton-Meier et al., 2008; Cavagnetto, 2010; Vygotsky, 1978). Language cannot be separated from science because it is viewed as a powerful learning tool. As Norris and Phillips (2004) indicated, there is no science without language. Thus, language is more than a text; it is a representation of knowledge (Hand, 2008).

Argument-based inquiry is undeniably a way of using the language of science as a cultural tool that people can use to communicate with others in their community (Lemke, 1990). Students have the ability to represent their thoughts and communicate their conceptual understanding to various audiences through the use of appropriate science language. Such communication may take the forms of scientific models, writing, or speaking (Newman et al., 1999; Vygotsky, 1978). In group discussion, language is also used as a tool for students to communicate and negotiate their ideas (Hand et al., 1997; Prawat, 1989). Oliveira (2010) further suggested that it is necessary to improve teacher levels of linguistic awareness since this awareness can enable science teachers to modify their verbal communication into the forms necessary for inquiry-based learning contexts, and allows them to better support their students' inquiry experiences.

Creating a range of environments in the science classroom is important in order to give students authentic opportunities to practice using science language in various forms, including written, read, and oral modes. Moreover, the classroom setup should assist students to use language to negotiate their claims with their peers in various learning environmental settings such as individual, small group, or even whole class (Lemke, 1990; Hand, 2008). Through these language environmental supports, students are able to develop their understanding of scientific concepts, cognitive reasoning, communication, and critical thinking skills (Duschl, 2008). Bransford, Brown, and Cocking (1999) mentioned that learning language supports the concept of science learning and leads students to a deeper understanding of the concepts. Overall, language is essential to the enhancement of scientific knowledge as it promotes science learning and is a tool of argument. Thus language is a crucial factor that needs to be addressed along with knowledge construction in the science learning process (Wellington & Osborne, 2001).

Questioning, Problem solving and Reasoning, and the Establishment of a Supportive Learning Environment as Keys to Enhancing Argument-based Learning

In order to enhance the shift from traditional teaching to argument-based inquiry, it is important that teachers create environments where students feel a sense of ownership of participation and feel free to argue (Hand, 2008). Teacher questioning, problem solving, and the establishment of a fostering learning environment are key components of argumentative learning. In addition, they are critical components to initiate the shift and are therefore the criteria focused on in this study.

Teachers' Questioning in a Science Classroom

In an argument-based inquiry classroom students are typically encouraged to construct their own knowledge through inquiry activities and negotiation processes (NRC, 1996). Questioning plays an important role in scientific inquiry learning to achieve the goal of reformed education (Chin & Osborne, 2008; Forbes & Davis, 2010). According to Cuccio-Schirripa and Steiner (2000), "questioning is one of the thinking processing skills which is structurally embedded in the thinking operation of critical thinking, creative thinking, and problem solving" (p. 210). Teachers' questions are then more valuable than direct teaching, as they promote students' dialogical interactions and develop their science learning (Hand, Treagust, & Vance, 1997).

It is clear that students' curiosity is a strong driver of the inquiry learning process (Bybee, 2002). Scientifically-oriented questions are often used as the first step of the five essential features of inquiry (NRC, 2000), which is called engagement. It can initiate students' sense of curiosity and focus their interest onto some natural phenomenon, or onto the task at hand. Scientifically-oriented questions also call upon and indicate learners' pre-existing knowledge, the assessment of which is essential because students in a class come from various societies and each of them holds different background knowledge. This stimulation of prior knowledge performs a number of useful functions. It not only helps students make connections between their existing and current experiences but also helps teachers to determine if students have learning problems or any points about which they are unclear (Chin & Osborne, 2008).

Argumentation involves the use of language as a learning tool to encourage both individual and social knowledge construction (Lemke, 1990; Duschl & Osborne, 2002). In this light, questioning is also growing in importance as an essential component of argumentation by integrating science language as a tool that can enhance the process of critical thinking (Chin & Osborne, 2008). Additionally, when students engage in these demanding question and answer sessions, they are in fact behaving like 'real scientists,' and thus classrooms really do become the training ground of a society's future scientists.

In an argument-based inquiry classroom, questioning is meaningfully used to engage learners in the lesson to elicit explanations, elucidate skepticism, justify reasoning, and evaluate claims and evidence (Martin & Hand, 2009). Teachers play a key role in driving reformed teaching practices (Prawat, 1992; Fetters et al., 2002). Teachers' questioning is viewed as significant in promoting improvement in student science learning. Thus, there is a need to encourage teachers to realize the importance of using scientifically-oriented questions, and to enact questioning in classrooms to promote students' cognitive and reasoning skills and ownership of knowledge, as well as to improve classroom talk that is relevant to the inquiry pathway (NRC, 2000; Forbes & Davis, 2010; Martin & Hand, 2009).

Even though questioning is an important entry into all conversations, many studies have mentioned that science teachers do not often ask questions or encourage students to ask questions during their science classes (Chin & Osborne, 2008). Due to this fact, questioning has not been used as an effective tool to promote student conceptual understanding (Weiss et al., 2003; Carlsen, 1997). Asay and Orgill (2010) assumed that this problem occurred because many teachers lacked an understanding of the importance of and how to use scientific questions effectively. Thus, it is clear that teachers need to better understand and ask scientifically-oriented questions in a way that supports cognitive learning. If teachers understand the essential elements of questioning, and are able to effectively develop their skills in conducting scientific questions, students will improve their critical thinking skills and be better able to respond to and pose their own inquiries (Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005; Chin, 2006, 2007).

Questioning is therefore a key tool that can drive learning and increase the authority of students' voices in the classroom (Martin & Hand, 2009; Cobb & Bauersfeld, 1995). Skillful teacher questioning can promote socially constructed knowledge since it triggers students to think, which can lead to group discussion that, in turn, leads to the generation of new ideas. Furthermore, questions promote students' scientific reasoning skills through the individual or group consensus process (Ladapat, 2002; Treagust, 2007; Hogan & Maglienti, 2001). The quality of teachers' questioning impacts classroom discourse because it enhances students' voices and creates a dialogical environment in a science classroom (Treagust, 2007). However, at present, high quality questions are rarely encountered in the science classroom. Most questions can be classified as low-level; examples include "fill-in-the-blank" and "short-answer" questions (Martin & Hand, 2009).

The NRC (2000) defined scientifically-oriented questions as those that are robust and fruitful in the promotion of student learning. In addition, profitable inquiry questions are those that are meaningful and relevant to students, answerable by scientific observation, compatible with student knowledge level, and appropriate to the development of student scientific knowledge and skills (p.25). Overall, the attributes of a meaningful question relate to its potential to engage learning (Freundlich, 1978). Effective scientific questions are therefore a required tool for teachers as they attempt to build up an inquiry-based learning environment in their classrooms. However, aligning their questions to the reformed learning style is a great challenge for science teachers (Penick, Crow, & Bonnsteter, 1996; Lapadat, 2002), and building questions to foster students' thinking and conceptual understanding can be a difficult process (Tobin & Garret, 1988).

In general, teachers need to become skilled in providing students with research questions that are appropriate to their age and knowledge level. This practice encourages students to contribute to and engage in lessons and to learn science well. Typically, "how" and "why" questions are specifically emphasized as they stimulate learners to proceed with their investigations and develop their explanations (Forbes & Davis, 2010). Additionally, the nature of the questions can determine how teacher-centered or learner-centered a classroom is. To be qualified as inquiry-based, high-level questions like 'how' and 'why' questions are supposed to fall into the range of learner-centered since they match with the goals of the inquiry-based instructional approach that supports active learners (NRC, 1996). On the other hand, a teacher-centered question normally requires students to produce a single "right answer" or respond with a simple answer that can be found directly in the textbook, instead of requiring students to come up with their own questions or modes of investigation (Crawford, 2000).

Questions that merely test student memory, such as vocabulary or 'yes/no' questions, are identified as low-level because they do not enhance students' cognitive performance levels (Bell, Smetana, & Binns, 2005; Bloom & Krathwohl, 1956). Further, *Bloom's Taxonomy* (Krathwohl, 2002; Bloom & Krathwohl, 1956) highlights that there are different kinds and levels of question with each being used for different purposes and being classified according to its potential to promote students' cognitive thinking. Those questions that involve a high level of cognitive thinking such as application, analysis, synthesis, and evaluation questions, are classified as significant questions that are an important part of the learner-centered classroom because their asking and answering involves the expression of students' voices. Moreover, such questions challenge students to articulate their understanding related to argumentation and reasoning (Bloom & Krathwohl, 1956; Martin & Hand, 2009). Thus, teachers' questioning is key in that it affects and encourages students' high-level cognitive functions (Bloom & Krathwohl, 1956; Krathwohl, 2002). Therefore, it reflects teachers' views of learning and their inquiry teaching practices in the classroom (Martin & Hand, 2009).

Problem Solving and Reasoning

Students' ability in problem solving and reasoning is one of the emphasized essential characteristics for learners in inquiry classrooms (NRC, 1996, 2000; Crawford, 1999; AAAS, 1993). Thomson (1984) indicated that teachers who realize the importance of conducting problem-solving strategies in their classrooms tend to employ inquiry-based learning. To succeed in inquiry-based learning, the emphasis is not only on content, but also on the epistemology of learning and investigative and problem solving schemes (Hmelo-Silver, 2004). Thus, teachers should provide opportunities in class for students to engage with questioning, scientific investigation, and argumentation (Hmelo-Silver, Duncan, & Chinn, 2007).

Problem-solving activities encourage students to work collaboratively in constructive processing and provide opportunities for them to discuss and share their ideas (Polman, 2004; Duschl, 2003; Hmelo-Silver, Duncan, & Chinn, 2007; Gillies & Khan, 2008). In addition, problem solving engages students in authentic inquiry investigations and develops their critical thinking and reasoning skills (Chiappetta, 1997; Gillies & Khan, 2008). Challenging students' skills in reasoning and elaboration is important as they can bring these skills to contribute meaningfully to dialogues while working with peers during their scientific problem solving (Mercer, Dawes, Wegerif, & Sams, 2004; Rojas-Drummond & Mercer, 2003). It has also been suggested that using problem solving collaboratively with learning fosters a deep understanding of concepts as well as helps student achievement on standardized tests (Hmelo-Silver et al., 2007).

Generally in a science classroom, teachers can construct inquiry activities by means of inductive and deductive activities. However, Chiappetta (1997) indicated that deductive activity, where the concepts precede the investigation or laboratory, is found most often in science classrooms. Thus, to promote students to become problem solvers, authentic experience and problem solving tasks are essential in that they engage students with the sense-making process, promote them to conceptually and empirically work on inquiry tasks on their own, and provide opportunities to reflect on their learning while immersed in the problem solving process (Quintana et al., 2004; Gillies & Khan, 2008). Hmelo-Silver (2004) explained the elements of useful problem solving activities:

> To foster flexible thinking, problems need to be complex, well structured, and open-ended; to support intrinsic motivation, they must also be realistic and resonate with the students' experiences. A good problem affords feedback that allows students to evaluate the effectiveness of their knowledge, reasoning, and learning strategies. The problems should also promote conjecture and argumentation (p. 244).

Literature has indicated that creating problem-solving strategies improves learners' cognitive and social dimensions (Goos, Galbraith, & Renshaw, 2002). In addition, it encourages students to seek alternative modes of investigation and become creative persons and active learners in order to discover the means to solve problems, represent, and interpret evidence (Wright, 2004). Through the process of problem solving, students involve the reflective process in their learning in that they have opportunities to question themselves about what they know, what they have learned, what they think, how they might transfer or apply knowledge to the current situation, and how they direct their own learning (Hmelo-Silver, 2004; Wright, 2004; Gillies & Khan, 2008). Doing this requires them to make connections between their previous knowledge and the existing problem.

Problem solving activities not only promote students' critical thinking, reasoning, and higher order thinking, but also challenge their social interaction skills (Wright, 2004). Problem solving and the learning environment are closely related. According to Dewey (1938), students can construct their own knowledge through learning from real-world problems. Therefore, usually problem solving activities are connected to real-world examples or students' lived experiences, which helps to engage and motivate them to learn because they can grasp the problem and perceive its value rather than just engaging with abstract problems that are far from their imaginations (Hmelo-Silver, 2004; Bandura, 1997; Crawford, 1999). In inquiry-based classrooms, students are typically structured to work collaboratively in small groups, which is a key strategy for promoting problem solving learning activities, involving students in the discussion process, and motivating them to cooperatively come up with explanations for problems (Hmelo-Silver, 2004; Gillies & Khan, 2008; Palinscar & Brown, 1988). Thus, students are challenged to debate their ideas through the process of problem solving activities.

The teachers' role during inquiry activities is crucial; they are key factors to encouraging students to talk, discuss, and share their thoughts and reasoning (Rojas-Drummond & Mercer, 2003). To support students to accomplish learner-centered learning, teachers need to decrease their authority in the classroom. Rather than explicitly informing students of the right answer or asking them to follow the teacher's instruction, in the inquiry-based class, teachers become facilitators who scaffold students' learning, engage them in problem-solving tasks, and challenge students' cognitive thinking and reasoning through inquiry investigations (Quintana et al., 2004; Hmelo-Silver et al., 2007; Hmelo-Silver & Barrow, 2006; Collins, Brown, & Newman, 1989; Goos et al., 2002; Hmelo-Silver, 2004). Research suggests that teachers must prepare themselves with the knowledge, skills, and ways of thinking to effectively mentor students during problem-solving investigations (Windschitl, 2001).

The Establishment of a Supportive Learning Environment

In most traditional science classrooms, the teachers typically 'teach' and 'drive' class activities, and the students' role is that of passive learners. The dominant dynamic is a one-way transfer of information from the teachers to the students, and little effort is made to encourage students to come up with their own arguments. On the other hand, the argument-based classroom is a transformed classroom environment; the roles of teachers and students are changed. Within the reformed class, teachers often play a key role in assisting students' learning by providing guided questions, but the most important role for teachers is to create a stage of dialogical discourse in which students can express their ideas and discuss them with their classmates (Simon et al., 2006; Ritchi & Tobin, 2001; Driver et al., 2000). A classroom inquiry environment that contains discourse activities offering students opportunities to debate their scientific claims backed up with evidence from their self-directed investigations looks different from a traditional classroom (Ash & Kluger-Bell, 2000).

To trigger the implementation of argumentative learning into a science classroom, it is important that teachers create a supportive learning environment that provides opportunities for learners to practice comfortably, and is conducive to scientific public debate (Berland & Reiser, 2009). In addition, the learning environment has to provide students the chance to gain an authentic experience of a scientific community, and to become active members of that scientific society (Quinn, 1997). Darby (2005) indicated that the quality of students' learning increases as they are engaged and motivated to participate in the lesson. Consequently, an appropriate learning environment is significant. If teachers believe that individual students can construct knowledge, and that students can learn through social interactions, it is more likely that they can provide a setting or opportunities for students to work with their peers (Atkin, 1996).

Teachers cannot, of course, directly transfer the skills of constructing arguments to their students because individual students have their own beliefs that are not suddenly changed upon listening to the teacher (Posner et al., 1982). However, what teachers can do is build an environment that allows students to think critically about their claims and evidence, and actively participate in arguments and debates (Simon et al., 2006; Newman et al., 1999). This should allow students to gradually develop their argument skills (Hand, 2008). Also, this is a necessary step to encourage young learners to confidently and skillfully present strong arguments in public (Berland & Reiser, 2009).

Simon and colleagues (2006), in their study of the way teachers support argumentative discourse in the classroom, stated that “teachers supported processes described as classroom culture, including the facilitation of student discussion and encouragement of students to supply evidence to support their claims” (p. 239). Through this lens, science learning is not just focused on students’ practices of scientific method, it also involves a deeper and more meaningful role for students as they articulate scientific claims and evidence and then argue their positions in a community, yielding to socially constructed knowledge.

As students practice organizing their work and arguing, it is likely that they develop better higher-order cognitive skills. Through this process, students gain a better understanding of the importance of socialization in a scientific argument. However, social skills and argumentative ability will not, in many cases, develop suddenly; the best and perhaps the only way to boost young learners’ abilities in this area is to let them practice by themselves. With practice, learners should become accustomed to the process of robust argument and become better able to confidently debate their claims in public (Driver et. al., 2000; Osborne et al., 2004; BOSE, 2008). The practice of argumentative discourse in the science classroom can then help students to learn more than mere facts; through practicing it, students can develop an understanding of how science actually works and proceeds (Ford, 2008). In addition, students are required to understand that science knowledge is a product of social construction; thus, the comprehension of social practice is needed (Driver et al., 2000; Driver et al., 1994). Apart from the opportunities for students to practice, the research to date has indicated that teachers’ longer waiting time to students’ responses tends to improve students’ cognitive learning achievement in that students generate more questions and response, share more ideas among friends, and have more contribution to the class’s activity (Baker & Piburn, 1997).

Learning can occur in different ways as teachers challenge students' ideas in various learning settings. Such settings may be individual, small or whole class and may involve the use of a variety of forms of expression such as writing, discussion, reading, or multimodal representations (Hand, 2008). The availability of alternative activities in a science classroom stimulates learners to be active, and enhances their understanding of the concept they are dealing with (Buarapha et al., 2006; Henriques, 1997). In addition, Fahy (2004) claimed that a variety of activities, once established in a classroom, encourage learners to structure their learning and to make their thinking visible, as well as help to engage students' interest and attention.

Cooperative learning such as group work is an effective strategy to build a non-threatening learning environment (Hand et al., 2009; Martin & Hand, 2009; Gilies & Khan, 2008) that minimizes cultural restraint (Flowerdew, 1998). However, there have been fewer studies focused on learning environment and the cultural perspectives (Flowerdew, 1998). In Asian cultures, students' presentation of ideas is not commonly practiced in public (Choi, Nam, & Seung, 2011). In fact, as Flowerdew (1998) argued, Chinese students will not generally talk out loud unless they are sure that their answer is correct. In a similar way, students in other Asians cultures do not want to feel the embarrassment of giving wrong answers in front of their peers. One answer to this problem is to create a supportive learning environment in the classroom, because students in such an environment know that that there is not a single right answer. Moreover, they know that everyone's voice is equal and that they all have the right to voice their opinions in public.

Flowerdew (1998) further stated in his study that group work is a useful cultural tool for Hong Kong students because working with classmates helps to promote student responsibility and sociability. It also reduces stress in the learning environment. His study reveals that when students are assigned to work in small groups, they seem to feel more comfortable about discussing their work and offering comments to their peers. Driver and colleagues (2000) also supported the claim about learning in groups to promote students' argumentation skill that "it is necessary to pay attention not only to the ways in which students understand the argument process, but also to the social skills necessary for conducting arguments in group" (p. 295).

Theoretically, to assist learners to construct their own knowledge or be active learners on the path described by the constructivist view of learning, the creation of a supportive learning environment is necessary since it will encourage students to think, talk, and argue about science critically without the stress of 'only one answer is correct' limitations (Akkus, Gunel, & Hand, 2007). As teachers create supportive learning environments, they should also make sure that students have enough time to think and get involved in the activity (Fahy, 2004).

The shift from a traditional classroom to an argumentative discourse classroom requires that teachers' role shift from being knowledge providers to persons who create a free and fair learning environment that is conducive to classroom talk (Ladapat, 2002). When the change is made, it is important that students feel a sense of ownership of their learning and feel free to initiate and share their new ideas. Under such conditions, learners are more active in classroom discourse (Erduran, Simon, & Osborne, 2004). When learners have the right to voice their ideas without the one answer only limitation, and a right to create, collaborate, and convey their arguments, learners enjoy authority over their learning (Duschl, 2008; Henriques, 1997; Flowerdew, 1998). In addition, engaging students in the authentic classroom where they have opportunities to discuss and perform their own learning would impact their beliefs and attitudes in science learning (Mason & Kahle, 1988).

The Science Writing Heuristic (SWH) Approach as an Argument-based Inquiry Learning

To implement an innovative teaching strategy or to shift teacher ways of teaching from lecture-based to student-centered, teacher's view of learning is a significant factor that needs to be taken into consideration since people's practices are interrelated with their beliefs (Leathem, 2006). To implement the argument-based inquiry approach into a classroom that has long been used to teacher-driven methods, change in teacher views of learning is certainly an important topic that must be considered. One of the approaches to support the shift from the traditional teaching approach to argument-based inquiry is the Science Writing Heuristic (SWH) approach. The SWH approach puts the NRC (1996) recommendations on inquiry learning into practice in the science classroom and the aim is to promote scientific inquiry learning. Theoretically, the SWH is an approach to promote student thinking and reasoning in science and it is based on a constructivist view of learning that embeds scientific argument into inquiry lessons (Hand, Wallace, & Prain, 2004).

In the SWH classroom, students are expected to actively demonstrate their understanding throughout the class as they ask questions, make claims and provide evidence (Hand, Wallace, & Prain, 2004; Martin & Hand, 2009). The SWH also promotes classroom discussion; learners are expected to present and negotiate their ideas with their classmates and teachers. The teacher's role in SWH classrooms is totally different from the role in a traditional classroom. Teacher's questioning and establishment of a non-threatening learning environment are vital to the enhancement of dialogical discourse in the classroom (Hand et al., 2009; Martin & Hand, 2009). According to the SWH Student Template below, the SWH approach aims to motivate student critical thinking, reflective thinking, reasoning, and active participation (Hand et al., 2009, p. 12).

1. Beginning ideas – What are my questions?
2. Tests – What did I do?
3. Observations – What did I see?
4. Claims – What can I claim?
5. Evidence – How do I know? What am I making these claims?
6. Reading – How do my ideas compare with other's ideas?
7. Reflection – How have my ideas changed?

The SWH approach encourages students to create and explore their original idea by getting them to pose questions or do concept maps before starting a laboratory work. All through the learning process, learners are encouraged to negotiate, and this includes individual negotiation in the form of proposing questions, writing down what they come up with, and data interpretation. Students are also encouraged to develop their social negotiation skills by sharing or discussing their ideas with classmates. Finally, students are expected to reflect on whether their ideas have changed over the course of the class, and support their changes of view with sound reasoning. Along with the SWH approach, teachers can develop their questioning skills in order to promote students involvement in classroom talk and articulate their scientific understanding. In addition, the processes of the SWH approach allow teachers to come up with ways to create a supportive learning environment, such as small groups discussion, in which students feel comfortable to voice their ideas and in which all students' voices are significant. Furthermore, students are challenged to play the major role as they investigate their questions, make their claims, build evidence, negotiate and reflect on their finding with peers (Hand, 2008).

Through the SWH process of lively debate, student ownership of learning construction is enhanced (Norton-Meier et al., 2008). When student ownership increases, teacher authority potentially decreases and this allows the shift from a teacher-centered style to student-centered fashion to occur (Martin & Hand, 2009). Once again, the SWH approach helps teachers to the shift their beliefs and practices from the traditional style to the constructivist view of learning, resulting in the embedding of argument into enquiry based classes.

Summary

This chapter presented the study's theoretical framework about the constructivist learning theory and the conceptual change, the shift of teachers' views of learning and their teaching practices, the factors that promote and prevent the shift of teachers' beliefs and practices toward the implementation of the new teaching approach. In addition, the relevant literatures associated with the critical element of the argument-based inquiry approach were provided.

The next chapter will discuss the methods of the study by elaborating on how the study explored the teachers' shifting process during their implementation of the ABI approach. In addition, data collection, data analysis, triangulation, limitations, and the implications of the study will be presented.

CHAPTER 3

METHOD

The method chapter addresses the foundation underlying the procedure selected for this study including: 1) the methodology framework, addressing the study's ontological, epistemological, and methodological assumptions. This section also addresses qualitative multiple-case study research, which was the empirical method employed in this study; 2) the research design used in this study involving the detailed description of qualitative research study, a multiple-case study, the role of the researcher, research context, the participants, and the role of the researcher; 3) data collecting techniques consisting of interview and observation, which were the main sources of data collection; and 4) the constant comparative analytical method, which was used to interpret and explain the phenomena of the study. The end of the chapter concludes with a discussion of the trustworthiness of the study.

Methodology Framework

This research study is based on certain ontological, epistemological, and methodological assumptions; this guided the methods and focus of interpretation (Guba & Lincoln, 1994). The Constructivist-Interpretative approach was employed as the research paradigm to guide this study (Hatch, 2002). In regard to the ontological assumptions of this paradigm, which are used to explain the nature of reality, it is believed that multiple realities exist (Hatch, 2002). The epistemological assumptions address the relationship (and are concerned with reducing the gap) between the researcher and the study being researched (Creswell, 2007).

The epistemological assumption associated with the interpretative constructivist paradigm is that reality is constructed by an individual through social interactions (Hatch, 2002; Grbich, 2007; Creswell, 2007). Thus, even though realities already exist, people cannot simply interpret their meanings objectively; rather, these meanings are constructed or interpreted in the way that makes sense to the individual based on his or her own life experiences aligned with their social context (Guba & Lincoln, 1994; Grbich, 2007). In other words, as Pattern (2002) indicated, the meaning of phenomena is derived from social negotiations (p. 203).

Research Design

Qualitative Research Study

Qualitative research studies are used to observe and interpret the meaning of the world (Creswell, 2007; Merriam, 1998). Denzin and Lincoln (2005) explained the characteristics of a qualitative study:

> Qualitative research is situated activity that locates the observer in the world. It consists of a set of interpretative, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memo to the self. At this level, qualitative research involves an interpretive, naturalistic approach to the world. This means that qualitative research study things in their natural settings, attempting to make sense of, or interpret, and phenomena in terms of the meanings people bring of them (p.3).

According to its characteristics and effectiveness as stated by Denzin and Lincoln (2005), a qualitative research approach was utilized to make sense of the complex world of teachers' views of learning and their teaching practices throughout the argument-based inquiry implementation process.

A qualitative study requires the researcher to stay in the setting as long as possible so as to gain information in great detail. As Creswell (2007) stated, "The longer researchers stay in the 'field' or get to know the participants, the more they 'know what they know' from firsthand information" (p. 18). Thus, in the research study context, it is common that participants and researcher(s) join together to construct knowledge and the understanding of the world via a process of social negotiation. It is therefore undeniable that the investigation of knowledge construction and a person's interpretation of meaning are subjective (Guba & Lincoln, 1994; Grbich, 2007).

A Multiple-case Study

A multiple-case study approach was the appropriate methodology for this study because the study aimed to explore deep and detailed descriptions of the shift in the participants' views of learning and implementation of the argument-based inquiry approach. A multiple-case study was utilized since it is an empirical method, which places emphasis on the study being conducted in a bounded system with the researcher gaining insight into the context by using multiple sources of data collection (Creswell, 2007; Merriam, 1998). To be more exact, the multiple-case study uniquely focused on one particular situation, which was the change in teachers' views of learning and their pedagogical practices. This particular study was centered on understanding meaning across each single case of how individual teachers shifted their views of learning and practices over one semester of the argument-based inquiry implementation process through searching for common patterns (Stake, 1995, p.8).

In the multiple-case study, relevant behaviors cannot be controlled; instead, it is essential to explain, describe, and illustrate the real-life context (Yin, 2009). This is a holistic method that takes various associated variables within the study's situation into account, ultimately providing a rich thick description to explain the complexity of the study's context (Merriam, 1998, p. 29). As a result, this methodological approach maintained the holistic characteristics of the real-life context and allowed the researcher to illustrate the meaning of the phenomena of the study.

Role of the Researcher

In qualitative research studies, the major role of the researcher is to interview and observe the participants in real-life situations in order to gain meaningful information for the study. Being a good listener is an important quality of a good interviewer since it provides a chance for the participants to articulate their points of view in response to a researcher's open-ended questions (Yin, 2009; Seidman, 2006). In addition, a good interviewer should be able to think fast to readily construct the next question based on a participant's reply. In this way, much purposeful information can be acquired.

In this study, the researcher did not act "behind the scenes," but rather became a part of the process by interacting with the participants. Hatch (2002) stated that researchers and participants can join together in the process of knowledge construction. Thus, throughout the observation phase, the researcher and the participants informally discussed, reflected on and exchanged ideas. These informal collaborations were undertaken with the participants after their classes had been dismissed or during teachers' break times. This type of collaboration allowed the researcher and the participants to construct and develop a deep understanding of the case study. However, the study's triangulation from multiple data sources was constructed to overcome biases that may have occurred because of these interactions (the issue of triangulation will be explained later in this chapter).

Context of the study

Schools

The three schools (Schools A, B, and C [pseudonyms], Table 3-1) that participated in this study are public secondary schools located in a small rural area in the southern region of Thailand. All three schools are large; each contains about 3,000 students. On average, there are approximately 40-45 students in each classroom, which is typical for a Thai class. These observational sites were selected because the teacher-participants had never experienced argument-based inquiry as a teaching and learning approach. Thus, this strategy was new to them.

Participants

The participants in this study consisted of five volunteer high school teachers with various levels of teaching experience. This study was based around physics teachers at the high school level because physics is viewed as a difficult subject for most Thai students. Soankwan and his colleagues (2007) stated that in Thai classrooms physics is typically taught via a traditional lecture-based approach, and this seems to affect students' lack of interest and to cause them to reluctantly engage in the subject matter. Physics teachers were also selected as the participants in this study because the researcher's major focus area is physics and the researcher plans to work with Thai physics teachers in her future career. Thus, familiarity with the physics teaching system is likely to be of benefit to further research following this implementation study.

At the beginning of the data collection phase, the researcher contacted the prospective participants to explain the study goals and activities, as well as to clarify the researcher's role when appearing in the classroom. This early contact helped the researcher to build up relationships and develop a rapport with the participants (Lincoln & Guba, 1985). During this process, five physics teachers were recruited. None of them had any experience with or had ever been involved in any professional development activities related to an argument-based inquiry approach. These teachers were willing to participate in this study because they wanted to gain experience with this new approach.

Teaching experience was not included in the participant selection criterion of this study because previous research (e.g. Guskey, 1988; Ghaith & Yaghi, 1997) has indicated that this factor was not considerably related to teachers' willingness to implement or the shift of their beliefs and practices with the new instructional approach. Furthermore, it is difficult to conduct classroom-based research in a Thai classroom since this is not commonly done in Thai schools. Thus, convenient sampling was used as a strategy to select the members of this study. Again, teachers' availability and their willingness to take part in the study were the main criteria for recruitment. Table 3-1 presents information about the participants in this study, including each teacher's name, gender, teaching experience, school name, number of students, and academic background.

Table 3-1 Information about the Participants

Teacher (Pseudonym)	Gender	Teaching Experience	School's Name (Pseudonym)	Teaching Level	Number of Students	Academic Background
Ausanee	Female	6	School A	10^{th}	44	M.Ed. Physics Education
Kamonwan	Female	15	School B	10^{th}	46	B.Sc. Physics Education
Sutisa	Female	16	School B	10^{th}	47	M.Ed. Physics Education
Kritt	Male	2	School B	10^{th}	30	B.Sc. Physics
Nattawee	Female	5	School C	10^{th}	45	B.Sc. Physics

Note: During the study's observational semester, all teachers were responsible for teaching both the 'Foundation Physics' and 'Advanced Physics' courses in a combination, excluding Nattawee, who taught only the 'Advanced Physics' course.

As seen in Table 3-1, the five participants involved in this study were experienced physics teachers from three public secondary schools. All of them were teaching 10^{th} grade with approximately 45 students in their classes. However, the participants' teaching experience and academic backgrounds varied. In addition to the teachers who participated in this study, three students from each class were also asked to participate in a student interview session.

The researcher used the same pattern to select three students—one male and two females—to interview from every class. More females were chosen because normally in Thai classrooms the number of female students is twice as large as male students. To select students using the same pattern, the researcher chose student identification number one among the male students in each class, and student identification numbers one and two among the female students. In total, fifteen students participated in the student interview sessions. The data collected from these interviews were used as supplementary data.

The Observation Unit

Throughout the observation semester, all participants focused on the same unit, "Force and Motion" which is the main physics concept situated in the 4^{th} strand of the Thai science curriculum (IPST, 2008). The aim of this strand is for students to have an "understanding of the characteristics and various types of motion of natural objects; having investigative process of seeking knowledge and scientific reasoning; transferring and putting the knowledge into practice" (p. 138). Within this unit, the curriculum requires students to be able to:

1. Experiment with and explain distance, speed, displacement and velocity of motion of objects;
2. Experiment with and explain how to find the resultant force of several forces on the same plane acting on objects;
3. Explain the resultant force acting on static objects or objects moving with constant velocity;
4. Explain the acceleration and the effects of resultant forces acting on objects;
5. Experiment with and explain the actionary and reactionary forces between objects, and put the knowledge into practice;
6. Experiment with and explain the relationship between forces and motion of objects in gravitational fields and put the knowledge into practice;
7. Experiment with and explain the relationship between displacement, time, velocity and acceleration of the motion of objects in a straight line (p. 136-139).

Throughout the semester, the five teachers must cover all of these curriculum requirements; however, the teachers can decide the order of the topics they plan to teach.

As their schools were located in the same educational service area, the teachers normally ordered the topics in the same way.

Research Procedure

Overall, this study consisted of three parts: baseline data gathering, professional development, and implementation phases. The baseline data collection process occurred during the first two weeks of the semester (May, 2012). Next, a one-day ABI inservice professional development workshop was scheduled immediately after finishing the baseline data collection. The following three months (June - August, 2012) of the semester were used for the data collection of the implementation phase. A data collection timetable consisting of the study's activities and the techniques used within each period of the data collection are provided in table 3-2.

After the baseline phase, professional development occurred in the form of a one-day workshop conducted by a professional development liaison who has rich experience working with the SWH project, which is aligned with an argument-based inquiry approach. The value of professional development (PD) is that it plays a significant role in inducing teachers to shift their views and practices toward a new strategy (Luft, 2001; Fetters et al., 2002). The power of talk and communication that occurs in the sessions allows teachers to express and reflect upon their ideas, and thus allows change to occur (Driver & Oldham, 1986). This study took these ideas into account by designing the interactive PD phase to encourage teachers to reflect, discuss, and share their opinions related to the learning and practice of a reform-based learning approach.

Contents of the Workshop

Overall, three main concepts related to the argument-based inquiry approach were highlighted in the workshop. These were negotiation, questioning, and language, as described below:

- *Learning is about negotiation (Hand, 2008)*

This topic focused on the critical elements of argument-based inquiry including claims, evidence, and negotiation in a science classroom. The SWH template was introduced as a guideline to explain how teachers could present argument-based inquiry in a classroom.

- *Questioning is a critical element of argumentation (Bloom & Krathwohl, 1956)*

This topic adopted Bloom's taxonomy to focus on the role of questions and questioning in order to enhance students' higher order thinking, as well as on the types of questions that encourage students' ownership of learning.

- *Language is a learning tool (Lemke, 1990; Norris & Phillips, 2003)*

This topic emphasized using various forms of language in learning along with conducting inquiry activities or reasoning problem solving situations. In addition, this part challenged teachers to come up with their own way of conducting a supportive learning environment to enhance the role of students' voices in their classrooms.

Generally, the contents of and activities conducted in the professional development session were taken from parts of the SWH inservice activities in the United States. The aim was to help teachers gain an understanding of their shifting roles in the reformed approach and to help them see how they could establish a dialogical interactive classroom in which students are able to generate questions, claims, and evidence for making an argument based on applicable reasoning (Hand, Wallace, & Yang, 2004).

In the workshop, to initially capture teachers' understanding of teaching, learning, and science, the professional development liaison engaged them with an introductory activity called the 'fish activity.' In this activity, each teacher had a chance to explore the fish material. They discussed what was causing the fish to act in a particular fashion. Then, the teachers were led to discuss and share their understanding of the critical aspects of learning science and how they could frame their teaching around big ideas and negotiation. Next, the teachers were introduced to the use of "Question, Claim, and Evidence" through the 'Mr. Xavier activity' (Norton-Meier, Hand, Hockenberry, & Wise, 2008). Immediately afterward, they were asked to take part in an inquiry investigation, which was intended to help them become familiar with the constructivist view of learning that embeds scientific argument with an inquiry approach. While doing this, the teachers again worked on the fish material. They practiced setting up research questions, designed an investigation, made a claim and supported it with evidence, and presented their outcomes. They also had opportunities to critique each other's findings and procedures.

In the afternoon session, the workshop mostly focused on teachers' reflection and their ideas about assimilating reformed learning into the physics curriculum or integrating the ABI approach with their class activities. In addition, this session was open for the teachers to share their classroom experiences, curiosity, and concerns they initially had with implementing the ABI approach. The professional development liaison also provided ideas for implementing the ABI approach into classrooms and elaborated the roles of questioning, problem solving, and a supportive learning environment in promoting effective student-centered learning.

Throughout the workshop, the attendees discussed and shared their classroom experiences. The professional development liaison neither forced the teachers to change their ideas nor required them to transform their practices following his strategy. Everything was entirely up to the teachers' decision. The schedule of this study's one-day inservice professional development workshop is provided in Appendix D.

As mentioned previously, after finishing the professional development workshop, the researcher scheduled weekly meetings with each teacher to interview and observe his or her class throughout the semester. These interviews and observations were used to assess and interpret the participants' views of learning and teaching practices, specifically focusing on their use of questioning and problem solving activities, and their implementation of a supportive learning environment in their science classrooms. Moreover, the researcher further examined teachers' concerns and the barriers they faced while implementing the new learning approach, as well as possible solutions to those barriers. The frequency of discussions between the researcher and the participants highlighted any emergent outcomes and revealed the shift in teachers' beliefs and practices with the reformed strategy.

Data Collection

As stated by Pajares (1992), "Beliefs cannot be directly observed or measured but must be inferred from what people say, intend, and do – fundamental prerequisites that educational researchers have seldom followed" (p. 207). Researchers need to infer meaning from what people say, and their actions can be an appropriate way to access their beliefs and practices as well as to investigate the changes in these aspects. Thus, in order to gain a deep understanding of teachers' views of learning, examining what they say, what they think, and what they actually do is necessary.

The qualitative multiple-case study approach used in this study aimed to provide thick descriptive data (Geertz, 1973) that could help the researcher track the complex changes that may have occurred in the teachers' views of learning and teaching practices by focusing on their progress in creating questions, introducing problem solving and reasoning activities, and providing a supportive learning environment. Gathering data to build up conceptual understanding, which is called the inductive process, is a significant component of qualitative research studies (Merriam, 2009).

Qualitative research is concerned with collecting data in a natural setting or in a site where the participants take part in the study (Creswell, 2007; Stake, 1995). Therefore, most of the data in this study were collected from the school settings, particularly in the classroom context in which each teacher performed their teaching. Observing the participants in their natural setting allowed the researcher a direct opportunity to record how they really talked and actually acted within their school context (Creswell, 2007). Thus, the researcher expected to observe and participate in authentic events.

As stated earlier, this study was grounded in a qualitative multiple-case study tradition that was suitable for exploring in-depth descriptions of one or more individuals. Rather than relying on a single data source, the use of multiple sources of evidence, such as teachers' interviews, students' interviews, classroom observations, and the researcher's field notes, helped the researcher construct the study's validity (Creswell, 2007; Yin, 2009).

The researcher spent approximately 14 weeks (one semester) in the school contexts for the data collection in Thailand. The data collection was conducted at three transition points: (a) During the baseline phase: before providing the teachers with the inservice professional development workshop; (b) During the professional development workshop; and (c) During the implementation period. Interviews, classroom observations, and field notes collected from the participants' classrooms were defined as the study's primary data sources.

Table 3-2 illustrates the timetable for data collection of this study throughout the fourteen weeks of observation. In addition, it reports the data collection techniques that were employed in each observation.

Table 3-2 Data Collection Timetable

Technique	Baseline Phase (May, 2012)		Implementation Phase (June –August, 2012)														
	Week																
	1	2	One-day PD workshop	3	4	5	6	7	8	9	10	11	12	13	14
Classroom Observation	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Lesson Interview	√	√		√	√	√	√	√	√	√	√	√	√	√	√
Reflection Interview	√								√					√	
Student Interview														√	
Researcher Field Notes	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Note: This plan of data collection was applied to all five participants. However, it was flexible depending on teachers' availability.

Interview

Interviewing is one of the most important techniques used when conducting case study research (Merriam, 1997). The essence of the interview approach is to help the researcher uncover the participants' experience, seek out the information that is in the participants' minds, and gain information about how they make sense of their world (Yin, 2009; Patton, 2002). In addition, interview technique helps to reveal information that the researcher cannot obtain directly from observation (Hatch, 2002). The common trend of interview questions in this study was to examine the participants' perspectives on learning and argument-based inquiry teaching with a focus on questioning, problem solving, and the establishment of a supportive learning environment. The interview approaches used in this study were the 'semi-structured interview' (Patton, 2002) and the 'in-depth interview' (Yin, 2009).

The semi-structured interview is, as its name suggests, somewhat flexible in nature, so the researcher is free to explore information in more detail than was originally stated in the interview protocol. How far this goes depends on the situation and on the participant's responses (Patton, 2002; Hatch, 2002). This interview technique is often used to examine teacher beliefs in the way they describe their thoughts and practices

(Kagan, 1990). In this study, the researcher conducted three types of semi-structured interviews: the 'Teacher lesson interview,' 'Teacher reflection interview,' and 'Student interview.'

The in-depth interview technique (Yin, 2009, p. 107) was also used in this study to engage the participants in great depth about their beliefs and disposition related to learning through an argument-based inquiry approach. All interviews conducted in this study were face-to-face and were recorded; participants were asked for permission to record prior to the taping. In this light, the audio recording was seen as a technique by which data could be taken directly from the participants and it was a useful resource as it allowed the researcher to revisit the verbatim conversations at any time (Seidman, 2006; Yin, 2009).

Teacher Interview

The researcher used the interviews to examine teachers' understanding, values, and beliefs concerning the argument-based inquiry approach. Interviews were also used as the principal evidence to identify the changes that may have occurred throughout the observation period. In addition, interviews were utilized to document teacher descriptions of barriers that impeded their implementation of the ABI approach. The interviews during the baseline phase specifically aimed to ascertain the participants' demographic information, and to identify their understanding about learning and their reflection of their own teaching before being introduced to the new instructional strategy.

Teacher Lesson Interview (Appendix A)

The teacher lesson interviews were scheduled weekly with each participant (Table 3.2). Typically, each teacher was interviewed before and after the class, depending on his or her availability. The interviews before the lesson were aimed at finding out what the teachers had prepared and the goals of the class, while in those interviews occurring after the class the teachers were asked to reflect upon what they had done, how, and how they performed those actions in the classroom. The teachers were also asked to compare ‘what they did’ to ‘what they had planned to do.’ The essence of the lesson interview was an attempt to clarify each teacher’s intention in conducting a lesson, and to compare that with the actual outcome. This data was used as evidence to reflect their views of learning and their actual teaching practices. In addition, this data further informed the researcher about the teachers’ views of learning and whether their practices had shifted towards the argument-based inquiry model.

Teacher Reflection Interview (Appendix B)

This type of interview was conducted three times throughout the observation period – before, during, and at the end of the study—to examine each teacher’s experience with the argument-based inquiry approach in the science classroom. Generally, the questions in this interview were divided into two major categories: questions about learning and questions about pedagogy. The reflection interview questions were thus primarily used to measure teachers’ ideas related to learning, their teaching goals, their views about the significant components of argument-based learning, the epistemology of science learning, language, and pedagogy, as well as the difficulties they experienced throughout the process. The questions also covered how each teacher viewed the use of questioning and problem solving and the construction of a learning environment as well as their concerns about the implementation of this innovative teaching approach. In other words, this type of interview was used to obtain both the teachers’ current views of learning and the pedagogy they believed they were performing.

Teacher Metaphor was another technique that was merged with the Teacher Reflection Interviews to determine how the teachers’ views of learning had changed over time. Thomas and McRobbie (2001) indicated that metaphor is a shared language method that allows the teachers to develop, reflect, and communicate their understanding of what learning means to them. Other studies have further suggested the power of metaphor to encourage teachers to change their beliefs because metaphor captures teachers' conceptualization of their role and teaching in the classroom. Thus, metaphor may cause teachers to change their classroom practices (Tobin, 1990; Berry & Sahlberg, 1996).

By using metaphor, teachers have the opportunity to reflect on their constructivist perspective of learning (Thomas & McRobbin, 2001, p. 227). Thus, this study also embraced this idea by asking each participant to create a metaphor from his or her outlook on the question 'What is learning?' This question was integrated into every teacher's reflection interviews.

Student Interview (Appendix C)

Student interviews were used as supplementary data to support the analysis of the teachers' beliefs about students' voices and their ownership in the science classroom; this information reflected the shift in teachers' views of learning and pedagogical practices. As previously described, three students from each class were invited to attend this interview session, and in total fifteen students participated. The questions generally aimed to obtain students' thoughts on:

- The way that science was taught during the semester and how the teachers used this approach in the classroom;
- The success or otherwise of the teachers' attempts at setting up a supportive learning environment and/or conducting of inquiry-based activities;
- How the teachers gave them the authority to come up with their own questions, claims, and evidence as well as opportunities to design or perform the investigations.

In a similar manner to the teachers' interviews, semi-structured interviews were conducted with the students. In each interview, the researcher asked the three students from each class to sit together. By doing this, they could jointly discuss and critique what they had observed about their teacher's instructional performance throughout the semester. This allowed the researcher to explore any changes from the students' point of view.

These three types of interviews (two teacher interviews and one student interview) were essential in helping the researcher to construct a clear understanding of the teachers' views of learning and revealed the changes that might occur during implementing the new pedagogical approach. These interviews assisted the researcher in articulating and tracking what changed and how the teachers began to change their views of learning and practice.

Classroom Observation

An observation is a useful strategy for more deeply exploring participants' actions (Hatch, 2002). It is the nature of case study to directly observe participants in the natural setting or the phenomena of interest (Yin, 2009). As this study was interested in tracking how teachers changed their views and practices toward an argument-based inquiry approach, the researcher conducted observations in the case sites such as classrooms as well as at other events like the professional development workshop and the informal meetings between the researcher and teachers. In the case of the professional development workshop and the informal meetings, the participant – observation technique (Yin, 2009, p. 111), in which the researcher and participants actively interacted and co-constructed knowledge, was used by integrating interview questions to challenge the teachers' ideas. Additionally, videos, obtained with the participants' permission, were recorded once or twice a week so that a permanent record of all activities in the case sites could be made (Yin, 2009). These videos were used to re-examine teachers' and students' interactions in class and were also used in the process of completing the RTOP analysis.

Researcher's Field Notes

The researcher's own field notes were used as one of the means of recording observations. Field notes were documented in the researcher's personal journal to record observations during each teacher's instruction, during the professional development workshop, and during the interviews with the teachers The field notes were intended to record the activity and reflect the researcher's own explanations of: how teachers implemented the argument-based inquiry approach; how they used questioning; how they conducted the learning environment; and how they interacted with students. These records were based on what the researcher directly observed, and were used as evidence to record the researcher's perception and reflection of all activities related to the teachers' actions. The researcher also used field notes to reflect on the success of the teachers' performances in each class throughout the semester. This "personal document" (Merriam, 1998, p. 115) was a vital source of continuous evidence that documented the changes that teachers might undergo during the semester. Selltiz, Jahoda, Deutsch, and Cook (1959, p. 327) have suggested that "such documents can tell the researcher about the inner meaning of everyday events, or they may yield descriptions of 'rare and extraordinary events in human life'" (cited in Merriam, 1998, p. 116).

When visiting the case sites, the researcher used the observation guideline (Appendix E), which contained twenty-one items that were classified into three observed criteria: learning environment, problem solving and reasoning, and questioning. With this field note guideline, the researcher could pay attention to the points of focus. The researcher also used this document to record her personal thoughts, comments, and reflections on each teacher's lessons.

To achieve consistency throughout the study, the observed criteria of the observation guideline was taken from the RTOP (Appendix F), which is the criterion used to score the videos from classroom observations. The idea of using the same criteria for both sources (video scoring and field note observations) was useful for triangulating multiple data on the same focused criteria. Table 3-3 presents how the researcher made notes during each observation. As illustrated, the researcher made notes and comments on the right side of each of the observed items.

Table 3-3 An Example from the Researcher's Field Notes Observation

Teacher… [Kamonwan]……………Date… [6/1/12]…………		
Category	Observed Criteria	Researcher's Field note & Comments
LEARNING ENVIRONMENT	8. Students were involved in the communication of their ideas to others using a variety of means and media (variety of types and scales of delivery).	Ask individual student to provide their answer orally with explanation Students shout a short answer of the factors to cause the uncertainty of measurement Ask students in each group to give their answer in the white board Students explain to the class. No discussion just saying out the answer and explanation. There are some competing ideas. Didn't encourage students to negotiate. She explains more from what the two students wrote.
	9. The focus and direction of the lesson was often determined by ideas originating with students.	
	10. There were a high proportion of student talk and a significant amount of it occurred between and among students (quantity of interactions).	
	11. Student questions and comments often determined the focused and direction of classroom discourse (quality of student interactions).	Students not only provide their answer but also explanation "because"
	12. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	
	13. There was a climate of respect for what others had to say.	
	14. The Lesson was designed to engage students as member of a learning community.	
	15. In general the teacher was patient with the students (mostly about the time).	Let students think and work in groups about the uncertainty measurement "I won't tell you what the uncertainty of measurement are, but I will have several situations for you to think first". Wait until most students have the consensus.
	16. The teacher acted as a resource person, working to support and enhance student investigations.	Summarize from what students just said "You don't have to look at the sheet. Write from your own understanding". She walks around and ask students each group to explain their answer and reasoning to the class.
	17. The metaphor "teacher as listener" was very characteristic of this classroom.	
Comments	- Lecturing is still the main characteristic of this class.	

Note: This table represents only a part of the researcher's full field notes called 'Learning Environment' criteria; the full version of the researcher's field note format can be found in Appendix E. This example was excerpted from teacher Kamonwan's classroom observation recorded on June 1, 2012.

Throughout the fourteen weeks of the data collection process, the researcher compiled a number of data from multiple sources of information, such as field notes and video and audio records, which contributed a rich description to promote the findings of the study (Merriam, 2009) and enabled strong triangulation of the data. Table 3-4 reveals the number of data collected for each participant from each data source.

Table 3-4 The Number of Data Collected from Each Data Source

Data / Teacher	VDO from Classroom observations	Researcher's field note observation	Teacher's lesson interview	Teacher's reflection interview	Student's interview
Ausanee	20	20	7	4	1
Kamonwan	21	21	8	3	1
Sutisa	19	19	8	3	1
Kritt	13	13	5	3	1
Nattawee	13	13	9	4	1

Data gathering from multiple sources of information, such as field notes and all quotes from video and audio records contributed a rich description to promote the findings of the study (Merriam, 2009), and enables strong triangulation of data to be constructed.

Data Analysis

As stated in Chapter 1, the research questions guided this study: (1) What changes occurred in teachers' pedagogical practices and their views of learning throughout their implementation of the argumentation-based inquiry approach? and (2) If change did occur, what was the relationship of the change among the observed criteria (questioning, problem solving, and the establishing of a supportive learning environment)? To answer these questions, this study employed the constant comparative method (Strauss & Corbin, 1990) as an analytical framework.

Constant Comparative Method

The constant comparative method (Strauss & Corbin, 1990) is an inductive data analysis process that performs a number of functions. The method generates and analyzes—it also integrates and makes conceptual links among categories and properties, as well as delimits and then captures the emergent theme (Dey, 1990, p.7). Essentially, the constant comparative technique is a “continuous comparison of incidents” (Merriam, 1998, p. 179). In this study, the constant comparative method helped the researcher to identify patterns in what was observed in the real setting, to explain if teachers had changed their views of learning and teaching practices as well as their change and the relationship among the observed criteria, without previously determined codes (Charmaz, 2000).

As discussed earlier, this study analyzed five participants and series of data collection sources. In order to organize the data of each individual teacher using the same pattern, the researcher divided the recorded files by the month in which they were collected. Thus, each participant’s data was labeled into a four-stage timeline: May (baseline data); and June, July, and August (implementation phase data). This allowed the researcher to systematically see the progression of each teacher in both beliefs and practices in every month. Furthermore, it was useful while comparing and contrasting the data across the multiple cases. This organizing strategy was applied to all types of data sources (teachers’ interviews, students’ interviews, and researcher’s field notes).

Data Analysis Procedure

After all relevant data was available for analysis, the researcher started with transcribing all audio-taped interviews in Thai, and then reviewed each interview transcript for accuracy. The interviews and field notes were mainly used as sources to access teachers' views of learning while the video observations and researcher's observation field notes were primarily utilized to understand teachers' instructional practices. Table 3-5 was created to summarize the data collection techniques and the focusing point it reflected on.

Table 3-5 Data Sources and the Focus of the Study

The Focus of the Study	*Data Source*
Teacher's Views of Learning	Teacher's Reflection Interviews Teacher's Lesson Interviews Researcher's Field Notes
Teaching Practices (Questioning, Problem Solving, Learning Environment)	Classroom observations • RTOP Scoring • Questioning Classification Teacher's Reflection Interviews Teacher's Lesson Interviews Student's Interview Researcher's Field Notes

Before identifying the emergent themes by generating codes from the multiple sources of data, all classroom videos were scored by the RTOP standard (Sawada, Piburn, Falconer, Turley, Benford, & Bloom, 2000). In addition, teacher questioning captured from the researcher's field note observations was additionally classified by Bloom's taxonomy (Bloom & Krathwohl, 1956).

RTOP Scoring as an Approach to Analyze the Classroom Videotapes

The researcher employed the "Reformed Teaching Observation Protocol (RTOP)" (Sawada, Piburn, Falconer, Turley, Benford, & Bloom, 2000) to analyze all videos from the classroom observations. The RTOP criterion is an acknowledged instrument to measure reformed teaching (Sawada et al., 2000). To align with the focus of this study, the researcher selected eighteen from twenty-five items of the original RTOP. Then, these eighteen selected items were collapsed into three categories (Appendix F) involving problem solving and reasoning, learning environment, and questioning, which are the critical elements of argument-based inquiry learning (Hand, 2008). A rubric of this scoring instrument was also created (Appendix G). The rubric was modified from "The Dayton Regional STEM Center (DRSC) (2011)", which is a reliable and valid instrument to evaluate inquiry teaching and learning implementation.

Using a Likert-type scale, each item of the RTOP was scored on a scale from 0-4; this scale was detailed enough to identify the teachers' level of implementation of each criterion. Then, the average scores were transformed into four levels of implementation: 0 = no implementation; 1 = low implementation; 2 = medium implementation; and 3 = high implementation. The results from the RTOP were used as the first identification of the teachers' level of implementation of the ABI approach. Furthermore, these results allowed the researcher to begin to answer the first research question about the changes that occurred in teaching practices.

Although the RTOP instrument was an effective measure of each teacher's reform-based teaching, the researcher noticed that this instrument had limitations for evaluating teachers' questioning practices, as it contained just one item focusing on this issue. Thus, the researcher decided to add three items to the questioning category; the idea of creating these three items was triggered by the NRC (2000). Additionally, the researcher further employed Bloom's Taxonomy to classify teacher questioning that was recoded from each classroom observation to allow for greater analysis of the questioning segment.

Bloom Taxonomy as a Tool for Question Classification

Bloom and Krathwohl (1956) identified different levels of questions to assess students' cognitive thinking. This study adopted this idea by classifying teachers' questions into three levels based on the degree to which they promoted students' cognitive thinking as shown in table 3-6.

Table 3-6 Questioning Classifications

Level of Questioning	*Type of Questioning*
Low	Knowledge
Medium	Comprehension and Application
High	Analysis, Synthesis, and Evaluation

Table 3-7 reveals how the researcher classified the questions teachers used in their classes based on these levels. The example in this table was excerpted from Ausanee's class recorded on July 9, 2012.

Table 3-7 Example of Questioning Classification

<table>
<tr><td colspan="4">Teacher… [Ausanee]……………Date… [7/9/12]…………</td></tr>
<tr><td>Level of Question</td><td>Type of Question</td><td>Teacher's Questions</td><td>Students' Questions</td></tr>
<tr><td>Low</td><td>Knowledge</td><td>What does "scalar" mean?</td><td>-</td></tr>
<tr><td rowspan="2">Medium</td><td>Comprehension</td><td>How can you get this answer?</td><td>-</td></tr>
<tr><td>Application</td><td>'Driving from Makri to Hat-Yai' and 'Dropping the fruit down': Do you think these are the same types of movement? Do you think these two objects moved in the same way?</td><td>-</td></tr>
<tr><td rowspan="3">High</td><td>Analysis</td><td>Note: The teacher used 2-3 pictures for students to clarify the difference between distance and displacement.

What difference between displacement and distance can you determine from these three pictures?</td><td>-</td></tr>
<tr><td>Synthesis</td><td>-</td><td>-</td></tr>
<tr><td>Evaluation</td><td>-</td><td>-</td></tr>
</table>

As shown in table 3-7, Ausanee used low, medium, and high level questioning in her class. Each question was used for a different purpose and different levels of questioning were used to enhance students' cognitive thinking skills. For example, she used a comprehension question, which was classified into the medium level, when asking, "How can you get this answer?" This question was targeted at accessing students' understanding of the concept as well as requiring them to explain their process in getting the answer.

The Constant Comparative Analysis Procedure (Strauss & Corbin, 1998)

The next step for data analysis was to code the interview transcripts. The researcher started with "open coding," which was a process to generate tentative data labels from each single observation that then could be used to compare and contrast with other data observations. At the beginning stage of data coding, the researcher began to review all the data from the two participants who performed the highest and lowest levels of implementation of the ABI approach reflected by the RTOP analysis. The researcher began with these teachers because she expected a variety of themes related to the main observed criteria to emerge from this data, which would be useful for the first step of generating the codes.

Next, the researcher made comparisons across the data from the interviews and field notes. This process generated more codes to describe the patterns among the data. The codes generated in this process were called "axial coding," and were produced by making connections among properties and dimensions across categories to rebuild core categories and subcategories for the data. To elaborate, the codes appearing in this step were assigned to sub-categories if they fell under the same category but presented in different ways. For example, after reviewing the data, the researcher discovered a main category that she labeled "Dialogical Interaction/Classroom Discourse" within the larger umbrella of "Learning Environment." Within this category, two codes were generated: "Teacher-student Interaction" and "Student-student Interaction." Thus, these two codes were assigned as the sub-categories of "Dialogical Interaction/Classroom Discourse."

Selective coding was conducted in the following step. This process aimed to validate the relationships among the generated categories. After completing the processes stated above, the patterns of the study were identified and reorganized into categories (Strauss & Corbin, 1998). As a result, a codebook (Ryan & Bernard, 2000) of this study was created (Appendix H). Table 3-8 shows some part of the full codebook to reveal as an example of this study's codebook. However, the full version of the codebook can also be explored in Appendix H.

Table 3-8 Example of the Codebook for Assessing the Shift of Teachers' Views of Learning and their Teaching Practices

Observed Criteria	Categories	Sub-Categories	Description	Example
Problem Solving & Reasoning	Inquiry Investigation & Problem Solving Activity	-	Focus the class on inquiry investigation and problem solving. Teacher encourages students' active participation.	Teacher provides a mathematics problem in her white board. Ask students to come out to solve a problem in front of the class (FO).
	Thought-provoking activity	-	Use interesting and challenging science activities that promote students' discussion/debating and students' critiquing. Also use activities that relate concepts studies in class to contemporary society issues which can improve student achievement and attitudes toward science	I taught Newton 1st law by asking them to work in-group on the variety situations I provided in that how these situations relate to the Newton law. I gave them time to think, analyze, and discuss in-group. How is the situation? Any forces act on the object? (LI).
	Reflection on learning (Meta-Cognition)	Reflect upon procedure	Opportunities for students to think about their learning and reflect their own understanding about the task/assignment/activity they are working on and the procedure how to get the answer	Most of my questions do not right to the answer that they have to get exact answer as the teacher's but rather I emphasize on the procedure that they use to get to the answer (RI).
	Reasoning	Elaborative reasoning	Students use or are encouraged to use evidence support their claim during negotiating or explaining	If they think it is wrong, they have to say how it is wrong. I want them to have reasoning. I want them to have thinking skill and think logically (LI).

The codebook generally contained the observed criteria of this study, which were the teaching practices (questioning, problem solving, and learning environment) and the views of learning. As illustrated in table 3-8, ‘problem solving and reasoning, which was indicated as one of the main observed criteria, was used as an example in this chapter of how the codebook was compiled. Four categories emerged along this major theme: inquiry investigation and problem solving, thought-provoking activity, reflection on learning, and reasoning. In general, the coding schemes were developed based on topics that were frequently mentioned by the participants (Mile & Huberman, 1994). In addition to the categories, the codebook also consisted of sub-categories, descriptions to explain the meaning of each category/subcategory, and real examples from the data sources (Field notes, Reflection interviews, and Lesson interviews) to help the researcher keep the steadiness while analyzing all of the data using this codebook (Dey, 1999; Strauss & Corbin, 1990).

After the codebook was generated, the researcher applied it to another teacher’s data to examine whether it was appropriate and functioned to adequately convey the phenomena of this study. Then, it was applied to the rest of the participants. Throughout this process the researcher used a note-taking strategy to record the emerging ideas (Dey, 1999; Strauss & Corbin, 1990). The patterns that arose from each participant were then compared and contrasted with each other. By doing this, all emergent properties and dimensions were taken into account. In other words, the data was inductively analyzed back and forth across several rounds until the categories were saturated (Glaser & Strauss, 1967; Creswell, 2007). The researcher then looked for the patterns of each individual participant and for the relationships across the five cases to draw storylines from the study.

Identifying the Emergent themes across Multiple-data

Sources and Multiple-case Study

Two research questions guided this study. In order to answer both questions, the researcher considered all data in two dimensions: horizontal and vertical scopes, as shown in figure 3-1.

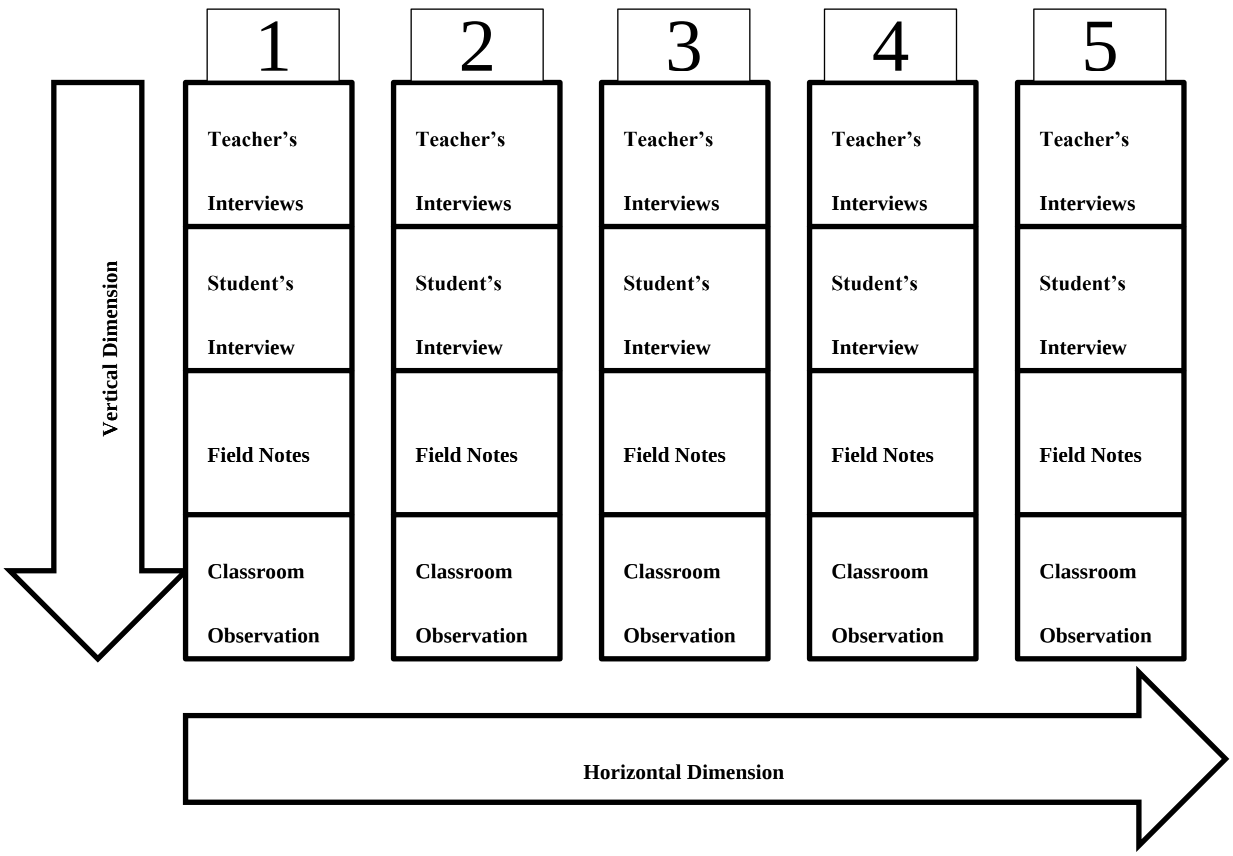

Figure 3-1 The Dimensions of Data Analysis

Research Question 1 aimed to determine what changes occurred in teachers' pedagogical practices and their views of learning throughout the implementation of an argument-based inquiry approach.

The vertical perspective played an important role in this stage. In addition to the teachers' practice scores, which emerged in the RTOP standard and Bloom's taxonomy questioning classification, other data sources were involved in answering this research question, including the researcher's field notes, teachers' interviews, and students' interviews. These sources of data helped the researcher to make sense of any changes that occurred in each case study. The researcher compared and contrasted each type of data during the four months of the study using the codebook to guide the focusing points. Doing this allowed the researcher to obtain information about what changes occurred throughout the ABI implementation phase.

Research Question 2 sought to determine that the relationship of the change among the observed criteria (questioning, problem solving, and the establishing of a supportive learning environment).

To answer the second research question, the researcher analyzed the data in both vertical and horizontal dimensions. Starting with the vertical dimension, this strategy enabled the researcher to sense the change of each teacher. The next step was to compare the outcomes across the five participants horizontally to reveal the shared characteristics of the change or the differences among the participants. In addition, using the same procedure, the researcher specifically examined the relationship of the three observed criteria vertically and horizontally across the five participants.

Triangulation as a Way to Reduce the Study's Subjectivity

Due to the nature of this research study, which tracked how teachers' views of learning and practices changed across time, it was impossible to avoid interactions between the researcher and the participants. Yin (2009) identified the problems of bias that can occur for a researcher using the 'participant – observation' technique (p. 112). As mentioned previously, all knowledge is subjective (Hatch, 2002), and it is impossible to produce a purely objective research study; all qualitative research studies encounter this issue. The important point is to figure out a way to eliminate those biases as much as possible. Triangulation plays a key role in reducing such bias (Hatch, 2002).

Using multiple data sources to explain one phenomenon contributed to data triangulation (Patton, 2002; Denzin, 1978; Stake, 1995). With this in mind, the multiple-case study triangulated multiple sources of evidence to affirm that the interpretations taken from all sources were constant; in addition, this approach increased the internal validity of the study and the certainty of information (Yin, 2009; Stake, 1995). The outcomes from RTOP scoring initially revealed how teachers had changed their practices or their implementation progression toward the argument-based inquiry approach. Likewise, using Bloom's taxonomy enabled the teachers' level of questioning implementation and their development throughout the semester to be tracked.

In this study, the researcher utilized several methods of data collection to achieve a better understanding of the changes in teachers' views of learning and pedagogical practices focusing on questioning, problem-solving, and the establishment of a supportive learning environment. The data taken from teacher interviews, student interviews, and the researcher's observation field notes allowed the researcher to find commonalities across all data sources.

When interpreting the results, the triangle diagram (figure 3-2) was used as a model to eliminate the study's bias because using only the researcher's or the teachers' lens was insufficient for gaining a reliable outcome (Merriam, 1998).

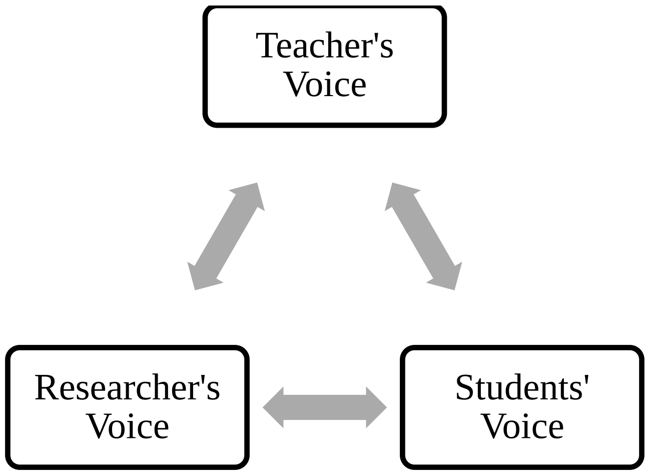

Figure 3-2 Triangle Diagram to Eliminate the Study's Subjectivity

According to figure 3-2, the teachers' points of view were taken from their responses in the interviews; students' voices were captured from interviews; and the researcher's voice was reflected in the field notes. These three main sources helped the researcher to interpret data in a balanced way, and thus diminished the study's subjectivity. The process of compiling and triangulating evidence from multiple resources enabled the researcher to eliminate subjectivity, reduced the significance of inaccurate interpretations of meaning, and bettered assessed teacher beliefs and how such beliefs and practices had really shifted throughout the implementation process (Pattern, 1992). Table 3-9 elaborates how the researcher conducted the study's triangulation via multiple data collection sources.

Table 3-9 Triangulation among the Multiple Data Sources

	Collaborative Learning	Classroom Observation (Researcher's field notes)	Assigned Code	Teacher's Interviews	Assigned Code	Student's Interview	Assigned Code
Establishing learning environment	Small group Group to group Whole group	**July:** Look at your answer. Compare it with your partner's in your group. You can raise your hand and ask a question if you wonder about the answer After done, leave your paper on the table. Group1 will correct group2's answer and so on. Let's see what we can get from each graph Note: Students brainstorm ideas Teacher assigns the problem and asks students to solve it in-group. Note: She said work in-group, but I didn't see any students' discussion or negotiation. At the very last minutes, she asks students to again work in-group. Each group got one question. Note: In-group, students discuss and negotiation the solution to solve their assigned problem. (Source: Ausanee: FO, 7/16/12)	**Small Group** **Group to Group** **Small Group** **Small Group**	**July:** R: You said this is the first time for this group of students to work in-group. So, what is the strategy you normally do in class? T: Previously, I usually use questioning. I asked, "is this correct? How should it be? But I never try to ask them to work explicitly in-group like today. R: What makes you decide your lesson by providing time for students to work in-group? T: Maybe I want to change and also I want to speed up the time. I want to find a technique, how to finish all 9 problems within 2 periods of class. In fact, if I teach them each problem, the time is not enough. Also, students may not get anything. But by this way, at least they will understand their group's question. By doing this, it can speed up the time and students can learn by themselves. R: How do you feel about today lesson? T: Overall, I think I may be too hurrying since I was concerned about time. But in the big picture, it is okay. Students seemed enjoy and not bored because they are not just listening my talking. (Source: Ausanee: LI, 7/16/12)	**Small Group**	**July:** R: Any activities in class? S: She asks us to work in groups. S: We demonstrate the solution on the white board. R: Do these activities promote your learning? S: It is good because she asks us to present our ideas with friends in groups…It is good.	**Small Group**

Table 3-9 contains an example excerpted from the “Learning Environment” category and “Collaborative Learning” sub-category, recorded from teacher Ausanee’s classroom observation on July 16, 2012. Within this situation, three main data sources were involved in the triangulation procedure. The researcher captured this class’s situation as it represented the idea of “Collaborative Learning.” As reflected in the field notes, three actions occurred in this class: small group, group-to-group, and whole group learning. The researcher found that ‘small group’ was the emphasized action recognized by the teacher herself as well as by the students in her class. Thus, ‘small group’ collaborative learning appeared to be a characteristic of the learning environment Ausanee constructed for this class.

Trustworthiness

In any qualitative research study, conformability, dependability, transferability, and credibility are the four issues employed to determine trustworthiness (Lincoln & Guba, 1985). Lincoln and Guba (1985) indicated that to ensure trustworthiness “careful checking of data codes, continuous scrutiny of data for internal and external consistency, triangulation, and continuous assessment of respondent credibility, are important steps to take as counter measures” (p. 282). Multiple data sources in this study were triangulated based on the same phenomena in order to boost the study’s validity. The results emerged through the process of triangulation; comparing, contrasting, and integrating increased the dependability, conformability, and credibility of the study.

To meet the credibility criteria of trustworthiness (Lincoln & Guba, 1985), this study built trust via prolonged engagement, which was a way to minimize misinformation from distortions that might be caused by the investigator or respondent (Lincoln & Guba, 1985). As stated in Lincoln and Guba (1985), “it is necessary to build trust and rapport with respondents while simultaneously guarding against ‘going native,’ that is, over rapport" (p.282). With this in mind, the researcher built rapport with the participants by visiting them at their schools before conducting the observations.

Peer debriefing was another technique used to develop credibility for this study (Lincoln & Guba, 1985). The researcher discussed the analysis with peer-researchers in the science education program and also regularly shared and discussed ideas with the advisor of this study to ensure all arguments, interpretations, and explanations met the study's goals and qualified to answer the study's research questions. In addition, member checking was used to strengthen the study's internal validity (Merriam, 1998). This technique was conducted with each participant after the completion of each classroom observation for debriefing and verifying the accuracy of what the researcher had obtained from the observation.

In terms of reliability related to the use of RTOP, the researcher of this study has experience in scoring several SWH project videos using this instrument. The researcher passed the training session and became a trainer for using this instrument to score SWH videos. Also, before beginning the RTOP video scoring, the researcher invited another Thai researcher to the analysis process. The two researchers practiced scoring on the same three videos selected from different teachers' classroom observations. Inter-rater reliability was 0.85 before discussion, and after discussion both researchers came to consensus. This process was used to boost the validity and reliability of the study.

In terms of transferability, Merriam (1998) and Stake (1994) stated the importance of qualitative studies whose findings or significance can apply to other or broader areas. This study provided rich contextual information to enable readers to determine how to transfer the findings to other situations (Lincoln & Guba, 1985).

Finally, the study's dependability and conformability were enhanced by triangulation of multiple data sources (Patton, 1990) as explained earlier.

Summary

The goals of this study were to examine the shift in teachers' views of learning and teaching practice as well as to explain the change and the relationship among the observed criteria. The qualitative multiple-case study was addressed in detail as a research method of this study. This chapter explained the study context, participants, and the procedure. Multiple data collecting approaches as well as the constant comparative method were discussed as the analytical framework that guided how the study attempted to answer both research questions. In addition, the chapter described triangulation, which was a powerful strategy used to reduce the study's subjectivity. In the next chapter, the results of the study are reported in detail, along with an explanation of the two research questions and the crucial points found in this study.

CHAPTER 4

RESULTS

As mentioned in chapter 3 Method, a case study technique was employed in this study because it helped the researcher to explore and provide deep and detailed descriptions of the shift in teachers' views of learning and pedagogical practices as well as their concerns as they occurred across the argument-based inquiry (ABI) implementation phase. To present the outcomes in detailed description, this chapter illustrates one-by-one the results of each individual teacher's view of learning, pedagogical practice focusing on questioning, problem solving and reasoning, and establishment of a supportive learning environment. Furthermore, it explores the concerns and difficulties that the teachers experienced throughout the semester.

Throughout the chapter several abbreviations appear in parentheses to distinguish the source of each personal communication between the researcher and the participants. To prevent confusion, all abbreviations are described in table 4-1.

Table 4-1 Identification of Abbreviations

Source	*Abbreviation*
Researcher Field notes observation	FO
Reflection Interview	RI
Lesson Interview	LI
Student Interview	SI

Note: In order to indicate the source of each quotation, the researcher lists the teacher name, followed by the source of information, and then the date the quotation was recorded (Teacher name: Source, Date). For example, "…" (Ausanee: RI, 8/31/12) means this quotation was taken from the Reflection Interview conducted with teacher Ausanee on August 31st, 2012.

As a result of RTOP analysis, figure 4-1 reveals the five participants' practice scores through the reform-based learning implementation process, categorized by month of observation.

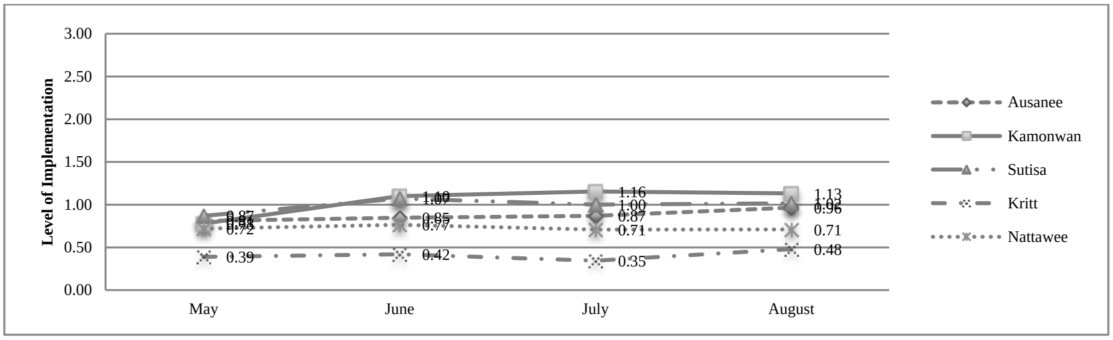

Figure 4-1 Five Participating Teachers' Inquiry-based Practice Scores Representing Level of Implementation of the ABI throughout the Semester

Figure 4-1 reveals the five participants' levels of argument-based inquiry implementation over the course of the semester. As illustrated, the scores of each individual teacher compared from the beginning until the end of the semester varied. Despite the fact that there was not a significant change in terms of the practice scores, this chart exposes the trend of the teachers' actions in their physics classrooms across the ABI implementation phase. It can be seen that three teachers performed the improved throughout the observation period while the other two teachers' inquiry implementation scores remained flat. Based on this outcome, the researcher thenceforth classified the participants into two clusters. The first was named 'the shifting group,' and consisted of Ausanee, Kamonwan, and Sutisa, the teachers who were beginning to change their practices. The second cluster was 'the non-shifting group,' involving Kritt and Nattawee, the teachers whose actions were consistently aligned with what they initially did.

The Shifting Group

Ausanee

Ausanee's instructional practice was classified into the shifting group as she showed some improvement on the three observed criteria (questioning, problem solving, and learning environment). She began her first month of the semester with the lowest teaching score compared to the other teachers in this group. However, her scores developed incrementally every month.

View of Learning

Ausanee primarily defined learning as a process where people gained new knowledge, which may either come from the teacher telling or from students pursuing information by themselves. In her opinion, the teacher's role was initially to build and prepare children's basic knowledge for a new topic, and then to encourage the students to apply their existing knowledge to different situations. As she explained, "Before they can construct their own knowledge, we should first provide them the basic information, such as theories or formulas, and let them practice by themselves as the next step. I mean we have to help them in the first step before the second step can occur" (Ausanee: RI, 5/21/12). As time passed, Ausanee slightly changed her view of learning, saying, "Learning is about students' knowledge construction. This knowledge would last a long time if the ideas came from their own thinking" (Ausanee: RI, 8/27/12). However, the teacher still believed that before students could construct their own knowledge, it was necessary that they obtain basic knowledge, which may come from a teacher's information or from the students seeking out information from other sources. Ausanee at the end of the semester appeared to realize that it was crucial to promote students to construct their own knowledge as this would lead to life-long learning and the students would benefit the most by learning this way. However, she commented that letting students perform their own learning might not be appropriate in some situations. For instance, low ability students still need the teacher to provide information before they can move to other steps. Therefore, the teacher seemed to be concerned about her students' ability; she thought it was difficult for them to construct their own knowledge without her initial elaboration.

The evidence from the interviews and field notes showed that Ausanee was satisfied with her students' improvement. She reported that one of her students told her that learning with understanding was good since he did not have to remember everything. She reflected that his message made her realize her students' ability to construct their own knowledge and this fact could be proved since the student seemed confident while explaining his problem solution to his friends. The teacher further stated that this made her feel good about the constructivist learning approach in that "The teacher cannot tell the learners everything. There are a million problems in the world. I have to just give them a concept. Then, they can construct their own knowledge and can apply that concept to every situation" (Ausanee: RI, 8/31/12).

Generally, Ausanee presented a positive attitude toward inquiry-based learning. She reflected that inquiry was about student-centered learning and was suitable to all science subjects, and further admitted the proficiency of ABI in that it promoted students to think, initiate ideas, and communicate their knowledge publicly. She also noted that it would be beneficial for learners if teachers could successfully implement this approach in their science classrooms. In addition to sharing her understanding of reformed learning and exposing her willingness to practice this approach, Ausanee revealed that she sometimes discussed with her colleagues possible ways to increase students' voices in the classroom. Moreover, she attempted to extend her optimistic attitude about ABI to these colleagues. For example, she suggested that the student teacher under her supervision provide more opportunities for the students to talk in class. She stated, "I gave advice to my student teacher. I think she typically does not foster her students to think enough but instead gives them the answer right away. So, I told her to try not to do that. The knowledge should emerge from the students rather than from the teacher telling" (Ausanee: RI, 8/16/12).

When asked where she placed herself within the process of promoting student-centered learning, Ausanee replied that her role had changed to a supporter or collaborator instead of the content-delivery position she had played before. She said, "I have now become a mentor. So, I am just a part of the learning process. In the classroom, the teacher is not the leader and the students are not followers like we have done in the past. I don't think it should be that way. Now, we collaborate, discuss, and share ideas" (Ausanee: RI, 8/27/12). The teacher also noted that she now realized the importance of promoting students' thinking skills, saying, "If they have logical or reasoning thinking, they can apply knowledge to other situations" (Ausanee: RI, 8/31/12). Ausanee shared her expectations with her students, explaining that she wanted them to be able to use their thinking skills in physics but also to transfer these skills to other subjects.

Even though she had a positive attitude toward ABI learning, Ausanee also brought up concerns. She mentioned that many teachers were not yet ready to support their students through the constructivist learning approach because they were concerned that their teaching techniques were not advanced enough to work with this reformed learning style. Likewise, Ausanee reflected that although her own teaching had become almost fully inquiry-based, she still feared that her technique might not be strong enough to support the students to become self-learners because she sometimes still provided them with information rather than letting them come to conclusions on their own. Possibly because of these factors, Ausanee noted that even though the effectiveness of inquiry was well known, Thai teachers did not often apply it into their classroom. She said, "Teachers usually design a lesson plan using an inquiry structure such as the 5E learning cycle model. But in fact, many of us do not really bring it into practice" (Ausanee: RI, 8/6/12).

Ausanee's worries about applying an inquiry structure in Thai schools were also related to her concerns about the classroom setting. She mentioned that Thai classrooms were normally very large since classes contained at least 40 students, which made it difficult for teachers to adequately check on their students. She stated, “As the number of students grows larger, it is difficult for a teacher to manage the class as well as design physics lessons suited to everyone in the class” (Ausanee: RI, 5/21/12). According to Ausanee, Thai teachers also face pressure from parents and students regarding students’ long-term educational goals. In her estimation, for many years the major goal of all students in the Thai educational system has been getting accepted to a university with a good reputation. Because of this widespread objective teachers are unable to avoid the pressures associated with students who are intent on doing well in their classes. She explains, “Students are very concerned about their grades because this impacts their chances of getting into a quality university and therefore their future career” (Ausanee: RI, 8/6/12). Based on these issues, Ausanee suggested that in order for Thai education to move toward a constructivist learning system, classes need to become less focused on grades; while this remains the case, students will continue to place less attention on learning concepts than on simply finding the correct answers.

Teaching Practice

As shown in figure 4-2, in terms of teaching practice Ausanee’s scores on the criteria of questioning, learning environment, and problem solving continuously improved throughout the semester.

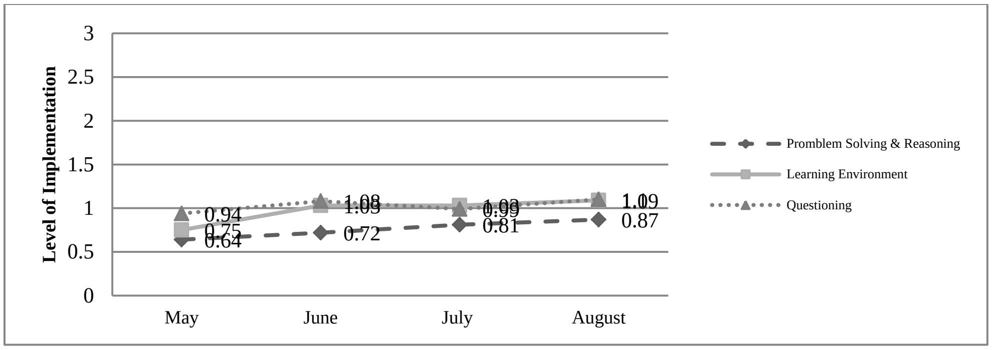

Figure 4-2 Ausanee's Level of Implementation of the Observed Criteria

Questioning

Ausanee stated that learning and questioning were correlated and she typically utilized various questions to engage her students in a lesson as well as to assess their conceptual understanding and learning achievement. She worked this question strategy into her classroom by "trying to randomly ask [students], not pointing to just a single student" (Ausanee: RI, 5/21/12). Ausanee further indicated that a right or wrong answer was not her ultimate goal, saying, "I am not disappointed if the students give me a wrong answer. It won't affect their grade. I rather prefer them to participate in my class activity" (Ausanee: RI, 5/21/12). The teacher also reported that her questions mostly aimed for enhancing students' thinking rather than focusing on their memorization. However, simple questions still appeared in her teaching, particularly at the beginning of the semester, because she thought that was the time to introduce the students to new physics terminology. Consequently, she could not avoid asking them about a definition or examining what they remembered concerning a new topic she had presented.

Based on the data from the researcher's field note observations and teacher interviews, questioning was the skill that this teacher repeatedly performed in the classroom. Figure 4-3 elucidates the types of questions Ausanee utilized throughout the semester. As formerly stated in Chapter 3 (Table 3-6), low level questions asked for knowledge and were relatively simple and focused on students' memorization; medium level questions assessed learners' comprehension and application of ideas; and high level questions gauged learners' analysis, synthesis, and evaluation skills.

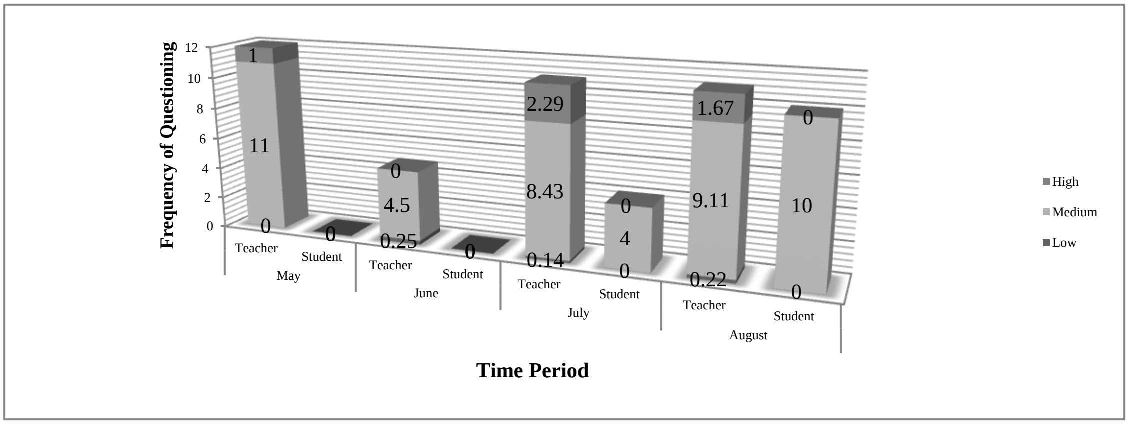

Figure 4-3 The Frequency of Questioning in Ausanee's Class

Figure 4-3 shows that Ausanee's questioning was varied; she used low, medium, and high level questions. However, medium level questions—especially application questions—far outweighed the other types and were consistently employed in her class; Ausanee asked medium level questions most frequently in every month of the classroom observations. It is important to note that even though she asked the highest number of medium level questions in the first month of observation, at that time Ausanee did not wait for student responses after asking questions. Although the number of questions decreased in the second month, the researcher's field notes indicated that during that month the teacher began to spend time waiting for students' answers. In subsequent months the number of questions she asked began once again to increase, as did the time she spent waiting for answers.

Early in the observation period, Ausanee mentioned her belief that “Problem solving is a key in learning physics”. This may be one reason why her questioning mostly focused on ‘application’ which is a part of medium level questioning since this encouraged students to apply theories or physics formulas to different situations. Her questions also sometimes drew on scenarios that connected physics knowledge to students’ everyday lives as a way to encourage them to employ problem solving. For example, she asked, “Mr. A drives his car from Hat Yai to Songkhla at a speed of 80 km/hr in 100 minutes. How many kilometers (distance) did he drive? How will you solve this problem?” (Ausanee: FO, 7/16/12).

In addition to consistently using medium level questions, figure 4-3 also shows that the number of Ausanee’s high level questions grew in July and remained elevated in August. At this time the teacher was using high level questions in order to encourage her students to interpret and analyze graphs as well as to identify the differences and similarities between the motion graphs. In these later months, Ausanee also showed improvement in using questions to promote students’ negotiation. It was observed that when she asked a question and a student answered, rather than directly evaluating his answer as she had done earlier in the observation period, the teacher instead pointed to another student and asked if he agreed with his friend’s explanation. She explained that her intention in doing this was “to check their understanding. Also, I want them to consider whether or not they agree with their friend’s answer, and to what degree. Why? Doing this requires my students to listen and think; otherwise, they won’t be able to criticize each other’s explanations” (Ausanee: LI, 7/9/12).

Even though improvement in her questioning skills was noted, the conversations between the teacher and her students many times finished quickly or sometimes just stopped immediately after one student delivered a short answer. For instance, when the teacher asked what students knew about the terms ‘quantity’ and ‘quality,’ the conversation ended instantly when a student responded, “Quantity is about a number but quality is not" (Ausanee: FO, 5/21/12). In another instance, when the teacher heard the answer that a scientific procedure was an exploration, she quickly ended the conversation and moved on to the next activity. Furthermore, some of Ausanee's questions just 'popped up' and then disappeared when she did not wait for the students' responses, and sometimes she would suddenly fill in the answer by herself. It should be noted that there were times when the teacher patiently provided opportunities for more than a single voice to respond to the same question. For instance, when asking, "What is a hypothesis?" there were two different responses: "It is the thing that we wonder" and "It is a thing that can possibly occur" (Ausanee, FO: 5/21/12). However, despite these positive questioning moments, most of the time students simply yelled out their ideas with no discussion or long conversation to follow them up. This situation frequently occurred during the beginning of the semester when the teacher's questions still just aimed for a short answer, which typically came from a single student. In later months Ausanee began to provide more time for class discussion, and even though this time was not extended enough for enriched conversation to occur, it was evidence of a potential pathway of development.

At the end of the semester, Ausanee critiqued her use of questioning over time. She stated that in every class she used both simple and problem solving questions in order to help students to think scientifically. The teacher pointed out that her questions in the later months increasingly stressed students' reasoning and critical thinking skills, such as asking them to compare, identify, or analyze the phenomena they were discussing. For example, "How does each situation shown in these pictures relate to Newton's first law of motion?" (Ausanee: FO, 8/16/12). As she explained, "To answer this type of question, they have to give me a reason why they think that way. 'How does the answer come out?' I will not accept if they just give me an answer without reasoning" (Ausanee: RI, 8/27/12).

Another significant point regarding Ausanee's questioning was that both her medium and high-level questions reached their highest number on the same day. In one of her classes in August, she conducted a cognitive activity by creating different scenarios and requested that students work in groups to come up with an explanation for their assigned problem. At that time, Ausanee started with a comprehension question, examining the students' understanding of the content she was presenting in her PowerPoint slides. She asked, "If the speed changes, what does it mean?" (Ausanee: FO, 8/16/12). Then she used application questions, which were delivered in both written and verbal forms, in order to encourage the students to practice solving problems as well as to enhance their critical thinking skills while asking them to explain the situation using Newton's laws of motion. Next, analysis and evaluation, which were classified as high-level questions, emerged as she asked, "Can you work in groups and compare the difference between these nine situations connected to Newton's laws of motion? Can you conclude Newton's laws of motion by using these nine situations as examples and then explain them to the class in your own words?" (Ausanee: FO, 8/16/12).

In addition to the improvement over time in Ausanee's questioning skills, another critical point that occurred in her class was the improvement in her students' questioning. During July and August, the teacher provided more opportunities for students to construct their own questions and encouraged them to argue their ideas with their friends. With this offered opportunities, the students did ask and construct their own questions. Mostly, the students' questions were related to the solution of the problems. For example, "Can we use this formula to solve this problem instead of yours? Why can't we combine F1 and F2?" (Ausanee: FO, 8/30/12).

Ausanee also claimed that her questions helped the students to construct their own knowledge because "Mainly, I use various questions. Most of the time, I use questioning along with class activities. The students have to think and answer my questions by themselves instead of just waiting for me to give the answer" (Ausanee: RI, 8/27/12). Her students confirmed that their teacher asked not only simple questions, but also questions that promoted them to think about the procedure and reasoning behind it. They said, "She asks several questions. In addition, she encourages us to demonstrate our problem solving procedure and also asks us to explain the phenomena in our own words" (Ausanee: SI, 8/23/12). The teacher reflected that her big change throughout the semester was in asking more questions and placing more emphasis on students' reasoning skills. She indicated that this change occurred because she wanted her students to think logically and to learn how to reason. She said, "How do you get this answer? What is the reasoning behind the answer? These are the questions I have recently asked more frequently" (Ausanee: RI, 8/27/12).

Problem Solving and Reasoning

As Ausanee believed that physics and mathematics were inseparable, most of the problem-solving activities conducted in her class were focused on the application of physics formulae, and many of them were related to mathematical calculations. Thus, she was trying to encourage her students to practice applying knowledge after they finished discussing the theory. In later months of observation, the researcher noticed that Ausanee conducted activities that required her students to use several modes such as equations, formulas, diagrams, graphs, and pictures to visualize their ideas while problem solving and also to use those modes in their explanations. For example, the teacher suggested to the students that they "should start with drawing what you get from the question. This will help you to see the bigger picture; for instance, in this case, the direction of this moving car. Then, it will be easier for you to figure out the solution to this problem" (Ausanee: LI, 8/6/12).

Encouraging students to think of alternative solutions was another significant teaching method that began to occur in July. Ausanee reflected, "I think students can come up with alternative solutions, but sometimes we were in too much of a hurry to finish the class. So, I decided to give them more time to think alternatively. I am not as concerned with the answer as I am with focusing on the source and where that answer came from" (Ausanee: LI, 7/18/12). The teacher continued her intention for the rest of the semester by encouraging her students to draw pictures, diagrams, and graphs to represent their ideas. The class on August 16th, for instance, clearly illustrated Ausanee's progressive teaching while conducting a problem solving activity through the ABI approach. During this class, she assigned students to work in groups and each group was assigned to explain a scenario using Newton's second law of motion. For example, group 1's question was, "What is going to happen to the passengers if the car is stopped immediately?" while group 5 was asked to describe, "How is the car moving when it is stopped after moving with a constant speed?" Within the group work, students started to negotiate, in that they tried to defend their claim and persuade their group members to follow their idea. This atmosphere continued to the presentation time; even though this time focused more on information transmitting by the presenters rather than on the development of ideas, the activity showed the students' improvement in their ability to communicate to the public.

Communicative discussion also occurred more frequently in July and August; at this time the teacher herself noticed that there were some negotiations occurring in her class, and reported that she was excited and impressed to hear her students arguing their ideas. She said, "I am satisfied with my students' performance. I want them to think about whether they agree or disagree with their friends' ideas" (Ausanee: LI, 7/9/12). The teacher mentioned that the reason she provided more time for students to discuss was because she believed that each student had his or her own ideas and it was normal that each of them would think differently. Accordingly, it was good for them to share and debate those ideas among friends.

As mentioned earlier, most of this teacher's problem-solving activities were related to the calculation of physics formulas. However, she later shifted her class activities to also focus on students' other skills—not just the ability to apply a theory to a calculation. For example, she stated, "Today's activity was not directly focused on just calculation. We did graph interpretation. So, I asked them to analyze the graphs by brainstorming their ideas in groups. This helped both me and them to evaluate their own understanding about the theory we have learned" (Ausanee: LI, 8/20/12). Ausanee further indicated that she had begun to think that the procedure was more important than the answer. As she explained, "I weighed the importance of procedure over answer because it guarantees that the learners know where the answer came from. If we emphasize just the right answer, it may not mean anything but a number. On the other hand, if we focus on the procedure, they will learn how to get the answer and they will be able to apply this knowledge to other situations" (Ausanee: LI, 7/18/12).

Over time, Ausanee's practice also became more focused on the students' ability to construct and validate their explanations of the phenomena. To encourage this, she waited longer for students to think and provided more time for them to construct their explanations. She did not let conversations end until the students provided her with their reasoning, and also encouraged students to use fewer words from the textbook. She told the class, "You should be able to think back and forth. Also, you have to know and be able to explain to others how this equation and the graph are correlated in your own words, rather than just relying on your textbook" (Ausanee: FO, 7/23/12). An example of this shift in the teacher's practice occurred during one of her classes in August. She asked the students to explain Newton's third law of motion from their own understanding. One student answered "$F_1 = F_2$", an equation which they had obviously memorized or taken directly from a textbook. Ausanee then said, "Explain from your own understanding. Do not just give me the equation" (Ausanee: FO, 8/23/12). Another illustration of this shift happened during a class activity in July. Ausanee divided the students into 8 groups and let each group work on a different problem. After the groups finished drawing their answer, the teacher asked each group to alternate reviewing the other groups' answers. Thus, each group got at least 7 comments from their peers. Ausanee suggested that this peer review activity helped the students to reflect on their own learning regarding whether or not they really understood the concept and also helped them to improve their reasoning skills since they were required to make comments on the other groups' answers. Along with the activity, the teacher provided time for students to talk about whether their ideas were congruent.

In accordance with her growing score on classroom practice, Ausanee indicated that her role had shifted to becoming a greater supporter of her students. She said, "My class is open to every student. The teacher is a supporter. We learn informally and this is consistent throughout the semester. Everyone is free to talk. They are welcome to share ideas anytime. What I have added to my class is opportunities for them to practice by themselves. We have more time for presentation and discussion that focuses on reasoning as well as peers' reflection" (Ausanee: RI, 8/27/12).

Time management and time constraints were often a part of Ausanee's reflection on her own teaching; she mentioned that time constraints sometimes impeded her ability to conduct an inquiry activity. However, she conceded that even though this was a big issue for every teacher, for her the problem actually depended on class management. She indicated that teachers should come up with a technique to make class the most effective for learners within a limited time, saying, "Even with a small amount of time, we should be able to manage our activity within the time we have" (Ausanee: RI, 7/9/12), and over the course of the semester she seemed to become less anxious about time management. Though she had previously mentioned this factor, she later informed the researcher that she had dealt with the issue by just discussing the main idea in class and letting the students learn the other related topics by themselves. In addition, to save time, she occasionally assigned a sub-topic for each group to learn and present to the class. She said, "I also want to condense the time. Like in today's activity, we discussed in detail the s/t graph. Then, I gave them an example to show them how the s/t and v/t graphs are associated. Afterward, the rest of our class time was used for the students to practice with other complex graphs using this basic knowledge. This activity not only saves our class time but also helps the students understand the concept well" (Ausanee: LI, 7/23/12).

In addition to the problems associated with time constraints, the teacher further mentioned that her class was limited in terms of its supplies. However, she did not think this was a big impediment to students' learning. Ausanee's solution to this problem was to compile multimedia presentations related to her topic on PowerPoint. For example, when learning about using Vernier Calipers and micrometers to measure an object, because she lacked the apparatuses to have her class practice with them in person, she instead collected many pictures of these instruments and asked the students to practice measuring the number from the scale on the pictures. She explained, "Materials are an important factor. Even though our physics classroom is inadequately supplied, I think I can handle it. It is not a big deal if we want to do it. It is up to the teacher to design the lesson; we can definitely get through this problem" (Ausanee: RI, 8/27/12).

Learning Environment

In terms of the criterion of providing a supportive learning environment, Ausanee employed several techniques such as calling a student's name to answer her questions, randomly asking students to demonstrate their problem solution in front of the class, and group work. Generally, she consistently conducted these various class activities. Ausanee mentioned that performing an experiment was not the only approach to conducting an inquiry lesson, as many teachers had understood. Instead, she noted that there were several other ways to do this, including using multimedia such as VDO or PowerPoint instead of doing a laboratory in case materials or time was lacking; however, she said that teachers had to provide room at the end of the class for students' discussion. Even though the communicative interactions in her class were still very limited, they did progressively grow over time.

Collaborative learning such as group work occurred in almost every one of Ausanee’s classes. However, rich discussion was still not a large part of these classes, especially in May. Mostly, the students just tried to complete the assigned problems on time. According to the researcher’s field notes, the students started to discuss and negotiate their ideas about the solution of the problems during July and August. Throughout this period of time, the teacher encouraged the students to discuss the solutions within their groups before presenting the group’s idea to the whole class. Ausanee thought it was more productive if students learned in groups since their peers were the same age and used the same language and thus could sometimes better understand each other’s explanations than the teacher’s.

As mentioned previously, at the beginning of the semester the class seldom included interaction among students or even between the teacher and students. Most of the time, it was characterized by simple one-way communication in that the teacher asked questions but did not wait for students’ responses. Alternatively, sometimes the interactions appeared in the form of initiate-reply-evaluate (IRE) in which the teacher asked a question, a student answered, and then the teacher evaluated that response (Forbes & Davis, 2010). Ausanee’s own assessment of the situation in her class during the beginning of the semester reflected this analysis: “From what I have noticed, the students are not often discussing or answering my questions. They like to just listen and wait until I give them the answers” (Ausanee: RI, 5/21/12). As time passed, however, even though her class activities continued to run the same way, the opportunities for students to express their ideas increased. For instance, the teacher more often asked students to present their ideas to the class and also opened the stage for the audience to ask questions.

A non-threatening learning environment was another significant setting Ausanee established in her classroom. In her opinion, whether or not students got the answer correct was not as important as participating in the class activity. She believed that students would not learn well if they were in depressing circumstances. Therefore, she did not blame students or ridicule them for their mistakes. She stated, “Everyone is free to talk. By doing this, I will know if they understand the concept. It is not good if we force them to learn or if they learn with tension because they will just be quiet, not asking questions or sharing ideas with the class” (Ausanee: LI, 5/21/12). During August, she added to this the opinion that students can also learn from their mistakes by deliberating how their answers were wrong. She thus began to encourage her students to reconsider and reflect on their thinking about why their answer was wrong and focus more of their discussion on how they could fix the mistake. She told them, “If you think this idea is wrong, you have to say how it is wrong” (Ausanee: FO, 7/30/12). This significantly changed the way her class operated at the end as compared to the initial time of observation.

Considering the class’s atmosphere, during the first month some students’ voices was heard, but most of the time students simply shouted out answers without any discussion transpiring. In June, the teacher started encouraging the children’s involvement in helping her figure out the solutions to problems. Then, they worked together to construct an explanation of the problem. However, during this time the teacher was still the chief person who talked and played the main role in class. This situation began to change in July and August when students felt more confident explaining their ideas. Even though sometimes these explanations were just short answer responses rather than elaborations, the students seemed less afraid of speaking out in public. There were also times when students automatically argued their ideas without teacher reinforcement when they thought the solution that the teacher was demonstrating on the white board was wrong. Based on these instances, it appeared that even though the students’ argumentation was mostly about applying a physics formula to solve a mathematical problem and did not employ strong evidence to support their explanations, the students were more confident in voicing their opinions. In order to support this claim, the following dialogue excerpt, which was taken from one of Ausanee's classes in July, reveals the discourse development of this teacher and her students.

> T: If the displacement doesn't change, what else also doesn't change?
> S: Velocity.
> T: Can you say more?
> S: If there is no velocity, it means the velocity is equal to zero.
> T: How about the second graph?
> S_1: As distance increases displacement also increases.
> S_2: The displacement of the first graph is the same throughout but the second one changes.
> T: So, this means what changes?
> S: Velocity.
> T: If the velocity doesn't change, what do we know from this point?
> S: Distance.
> T: It is not related to distance.
> S: Velocity.
> T: Is it? Are you sure?
> T: What is its displacement?
> S: Zero.
> T: Why zero? Whoever answers zero should have a reason.
> S: Because it returns to its starting point.
> T: Think about when you are driving. When you drive for 10 seconds, is the distance still the same?
> S: No.
> T: Even though you drive with the same speed, you still get distance from driving. So I am asking you if the speed doesn't change, what is equal to zero?
> S: Velocity.
> T: Why?
> S: Because the initial speed and the ending speed are equal.
> T: Good (Ausanee: FO, 7/23/12).

This conversation demonstrates that the teacher used probing questions and attempted to ask the student to elaborate; at the same time, the student also learned to provide a reason with her answer. It should be noted that this situation was not found in every class but it was likely to occur more often in August than in May.

The role of the teacher was another important issue to consider while observing the teacher's implementation of an innovative teaching approach. Even though Ausanee presented a solid understanding of the element of student-centered learning, to some degree she still performed her role as a knowledge dispenser, particularly during the beginning of the semester. As time passed, the teacher as a talker was still the main feature of this class; however, it should be remarked that the teacher put effort into shifting her role in the class, such as providing more opportunities for students to discuss in groups and to present their ideas to the whole class. Nevertheless, the teacher still more or less controlled students' investigations and presentations. In other words, the class still employed traditional hands-on activities, or what it was called the 'cookbook.' The teacher took on a clearer role of mentor in August. Even though at this time the class was still not completely inquiry-based, where students were unrestricted in conducting their own investigations and fully claiming responsibility for their learning, the teacher did provide more opportunities for students' involvement in both investigation and presentation.

Kamonwan

Kamonwan was classified into the shifting group as her view of learning and her performance continuously improved toward the ABI approach. In addition, she was the teacher who achieved the highest score among the five participants in this study. Typically, Kamonwan was enthusiastic about having the researcher visit her classroom. She moreover was eager to share her thoughts about how she came up with the class investigation and about her expectations for student learning.

View of Learning

Similar to Ausanee, Kamonwan believed that learning can occur when a teacher initially gives information and then encourages learners to apply that knowledge to other situations. She explained, "They will have to insert this information into their existing knowledge in order to construct their own understanding. However, first we have to give them the information and ask them to apply it as the next step. By doing this, they can construct their own knowledge" (Kamonwan: RI, 5/25/12). According to her explanation, Kamonwan thought that prior to encouraging learners to construct their own knowledge, it was important that the teacher provide them with fundamental information. This notion corresponded with her students' outlook in that they preferred student-centered learning because it allowed them to contribute their own knowledge, even though they needed the teacher to give them information at first. As time passed, however, the teacher's ideas about learning shifted. Near the end of the observation period, she said, "Now I think learning is about everyone participating in class activities and being able to design their own investigations. I think students learn better this way than when the teacher is the only one who transfers knowledge and students are just receivers" (Kamonwan: RI, 8/31/12).

From the beginning, Kamonwan believed that it was possible for negotiated learning to occur in a science classroom because each individual holds different ideas. Therefore, teachers and students can share and argue their ideas. The teacher believed that both the teacher and the students played important roles in the classroom. However, in her first interview she emphasized that the teacher had the main responsibility to help students comprehend information based on the curriculum. Kamonwan did not really believe that student-centered learning could be applied in every situation, stating, "For instance, in my school setting we have mischievous students. Thus, we cannot employ a student-centered learning style 100% of the time. We have to use both old and new approaches. I think this reformed learning works well particularly with the high-ability students" (Kamonwan: RI, 5/25/12). She also commented that some of her students were not skilled enough for self-directed learning. However, two months later her ideas had shifted in that she thought teaching both high- and low-ability students could occur through a similar process since the focus was now on students' thinking and not just on the teacher providing information as before. She now had come to think that all learners have their own intellect and each of them can construct their own knowledge. Thus, the barrier of students' ability to absorb knowledge seemed no longer to be a problem to her.

Time was another dilemma Kamonwan brought up during her implementation of the ABI approach. She initially reported that it would take time to employ inquiry learning in the classroom since it required more time for students to practice on their own. Two months later, however, she informed the researcher that this worry had begun to subside after she tried implementing the approach. She now stated that, “I was worried that using this approach would delay our class time. However, I keep trying to do it more often. I just compare my class to the class my mentee is teaching; even though she uses the traditional teaching method, I found that we are going the same speed and can finish the unit at the same time” (Kamonwan: RI, 8/10/12). Kamonwan’s decreasing anxiety about time was also revealed in a class in July, when the teacher mentioned that she was less concerned about time than she was about her students’ learning; as she explained, “I would rather have them obtain a clear understanding of the concept because this is the basic knowledge they will use in the future” (Kamonwan: LI, 7/24/12). By the end of the semester, it was clear that time was no longer an issue for Kamonwan. She felt she could handle it now and the students seemed familiar with her new way of teaching. She said, “The students said it is better to know the source of knowledge. They seem enthusiastic; maybe this is because they are relaxed since I said it is okay even if you give me a wrong answer. It is totally fine. We can exchange ideas or you can change your ideas” (Kamonwan: RI, 8/31/12).

When asked about the national educational test, which was an issue with which every teacher was concerned, Kamonwan mentioned that it was not her problem. She reflected that as long as she covered every required topic in the curriculum, everything should be fine. However, she did admit that sometimes it was difficult to control the class since students came in with different learning goals; for example, some of them came to gain knowledge while many of them simply wanted to do well in order to graduate and get accepted to a university with a good reputation.

When asked where she placed herself in the inquiry teaching and learning process, Kamonwan stated that she viewed herself as playing every role in the classroom, including those roles of listener and mentor. She further mentioned that teachers actually needed to play a crucial role in promoting students to apply knowledge to different situations. However, she still claimed that the teacher should provide students with basic information first because without this students would not know how to work through a problem if they had no experience with a new topic. Despite holding on to this view of the teacher as the main provider of knowledge, Kamonwan indicated that she had adopted some ideas she learned from the ABI workshop to her classroom. For instance, she was trying more often not to give direct answers to the students but rather to provide more time for them to think and discuss. She reflected that what she did in her class was similar to the SWH design, even though the step had a different name. She explained, “The common idea is that we also have a ‘claim’ since each student has their own idea. They can explain why their answer is reasonable using ‘evidence’ from observation. We actually have everything similar to the SWH method but we just don’t organize it into a step” (Kamonwan: LI, 6/1/12). Kamonwan’s view of learning gradually changed after trying the ABI approach. She explained, “I want my students to be able to conclude the concepts from their own understanding in their own way so each of them can think differently” (Kamonwan: RI, 8/31/12). Clearly, she had realized the importance of student-centered learning, and she expressed her intention to provide more opportunities for students to learn by themselves, saying,

> I aim to change my teaching activities to focus more on students’ participation. I am okay teaching this way and I think the students like it too since they said to me, ‘Teacher, please don’t tell us the answer now. I have almost figured it out.’ This is opposite from what I heard before in that they usually said, ‘Teacher, please give me the answer’ (Kamonwan: RI, 8/31/12).

Kamonwan noted that it was possible for Thai education in general to move toward reform-based learning just as she had within her own classroom. She commented, “We should reduce the teacher’s role in the classroom. Then, we will know whether the students understand what we have taught them. In the past, I just talked because in our students' case they won't have any questions if we don't push them. I think they don't understand the concepts well and they don't even know what to ask" (Kamonwan: RI, 8/10/12). The teacher further expressed her satisfaction after being introduced to and trying to implement this new approach in her classroom, as she sensed that her students now seemed more confident in negotiating their ideas. She informed the researcher that she would continue to improve her teaching and would find more techniques to promote her students' achievement through a student-centered learning approach. She also advised other teachers who were deciding whether or not to implement reformed learning that they shouldn't "be afraid to try something new. It is indeed good for our students. They will become more confident in thinking and expressing their ideas" (Kamonwan: RI, 8/31/12).

<u>Teaching Practice</u>

In terms of teaching practice, Kamonwan performed a shift in all three observed criteria as shown in figure 4-4.

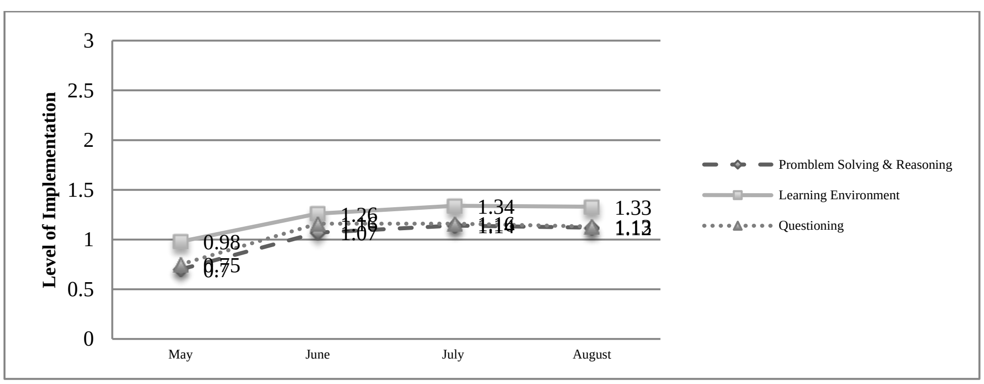

Figure 4-4 Kamonwan's Level of Implementation of the Observed Criteria

Figure 4-4 shows that this teacher developed in all observed criteria across the semester. Her highest score was in learning environment establishment, and this criterion was consistently and thoroughly developed throughout the study. Simultaneously, Kamonwan's questioning and problem solving skills also improved over time.

Questioning

In terms of questioning practice, Kamonwan started her first month by addressing only a small number of questions to the class and by waiting only a small amount of time for students' responses, as shown in figure 4-5. However, the number of questions she asked rose in the second month and continuously increased in the following months. These questions were primarily medium-level, though it was evident that she also attempted to develop high-level questions.

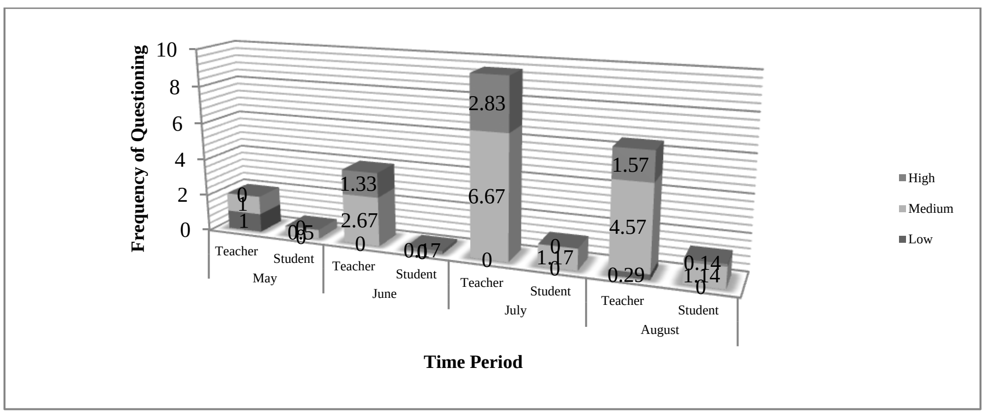

Figure 4-5 The Frequency of Questioning in Kamonwan's Class

As mentioned earlier, Kamonwan's questioning in the first month was very limited. But while attending the ABI workshop, she was introduced to the significant role of questioning in the classroom. This may have been a starting point for her to try implementing questioning in her physics class, and the change was noticeable, for example, when she talked about ‘graphs in physics.’ During this class period she did not lecture 100% of the time as she had done previously, but rather led the discussion with questions that motivated students to think about the topic, such as “What is this graph telling you?” In addition, she asked more questions in order to hear the students’ opinions and aimed for them to practice evaluating their peers’ answers; for example, “Do you agree with your friend’s answer? Do you want to change your mind? Can you explain why?” (Kamonwan: FO, 6/1/12). Despite these changes, however, the teacher still did not provide much time for the students to think after she had delivered these questions.

Kamonwan included different levels of questioning that were used for different purposes; this was congruent with her intention to promote diverse questioning in her class. In this light, she first used questioning to involve students with the lesson. For instance, she dropped a tiny rock in different positions to get the students to engage with the concept of ‘velocity.’ Then she prompted students to think, by asking “When I throw this rock up in the air, can you explain its ‘initial velocity (u)?’ What if I drop it?” (Kamonwan: LI, 8/10/12). Kamonwan also used questions to examine students’ comprehension, such as “What can we find from analyzing a linear graph?” (Kamonwan: FO, 7/10/12). In addition, she asked questions that were purposely designed to trigger divergent modes of thinking, especially when combined with problem solving activities. For instance, she would ask things like, “Can we use another formula to solve this problem?” (Kamonwan: FO, 7/10/12). The teacher explained that she would ask these kinds of questions because “It promotes students to think in a different way. Like today, the students expressed various ideas. Some of them can think out of the box, which is good” (Kamonwan: LI, 7/3/12).

It also appeared that many times Kamonwan used questioning to encourage students’ investigation, such as, “If we move the paper faster, what will the points look like? Otherwise, if we move it slower, would the points be the same?” (Kamonwan: FO, 7/13/12). Other than 'how' and 'why' questions that aimed for students to elaborate upon their answers, the questions that appeared most often in her class were those that developed the students' critical thinking and problem solving skills. For instance, the teacher would ask questions like, "What is the area under this graph? How many forces are acting on this object? How do we find the displacement of this object? What are the similarities and differences between your friends' and your own answers?" (Kamonwan: FO, 7/27/12). In later months, Kamonwan also attempted to extend the conversation by using probing questions to elaborate students' ideas. For example:

> T: How could we solve this problem?
> S: Find the area under the graph.
> T: Why did you decide to solve it this way? Can you clarify?
> S: To get the distance at the third second.
> T: Can we do this in any alternative ways?
> S: Find a slope.
> T: Find a slope for what reason?
> S: Because slope is equal to velocity. (Kamonwan: FO, 7/31/12)

Another significant development that occurred during the observation period was an increase in the students' engagement in questioning. During July and August, students started to ask questions in class. Previously, the questions just came out when they were curious but it was rare to have a discussion following up the questions, or sometimes the teachers just answered the questions by herself. However, as the semester progressed, the students' questions actually began to improve. Previously, they had asked simple questions such as "What is a unit of force?" (Kamonwan: FO, 5/25/12). Later, they asked questions that reflected their concentration and their understanding of the lesson, like, "Teacher, we used different methods, so why are our answers the same?", and their questions also became more complicated; for instance, "Teacher, when throwing a rock up into the air, what is the time at the highest point it can go and the time when it touches the ground? And how are they different?" (Kamonwan: FO, 8/10/12). Students also sometimes responded to their friends' questions without prodding from the teacher. For example, when one student asked, “Why is the acceleration negative?” another student then suddenly answered, “Because the speed is decreasing” (Kamonwan: FO, 7/13/12).

At the end of the semester, Kamonwan reflected that in order to integrate more questioning into the class she had begun to lessen her reliance on the textbook. She said, “Previously, I would bring only the book to class. But now I prepare more questions. I have searched for more information and have a variety of questions that I ask my students” (Kamonwan: RI, 8/31/12). She additionally analyzed the shift in her questioning practice, remarking that, “Earlier, I often asked ‘Do you understand?’ and the students just said ‘Yes.’ But now I have changed to asking, ‘What do you think? Do you agree? Do you have a different idea? Do you want to change your idea after listening to your friends’ explanation?’” (Kamonwan: RI, 8/31/12).

Problem Solving and Reasoning

At the beginning of the semester Kamonwan characteristically played the role of the teacher as a demonstrator. Rather than providing opportunities for students to explore knowledge preceding their formal presentations, she first demonstrated or lectured about topics such as how to create a tail-to-tail vector, how to use a Vernier Caliper to measure an object. However, as the semester progressed she did try to give examples and brought in several pieces of equipment to help students visualize their learning; for instance, creating a plastic arrow as a model to represent the connecting vectors. During the second month of the semester the teacher started to encourage students to use modes such as pictures and diagrams while solving problems or to support their explanations since she believed drawing pictures would help the students to see problems more clearly. She told the students, “Another important thing—and it is the first step—is that you have to be able to draw a picture to visualize your understanding of the problem. This could help you to more easily sense the problem” (Kamonwan: LI, 8/24/12). In addition, she tried to adjust her teaching methods to engage students in the investigation. For example, instead of asking the students to follow her instructions step by step, she provided an instruction sheet and asked them to learn from that material and play with the instrument by themselves. Even though this was not a full inquiry investigating approach in which students had complete authority to design their own investigation, it was a step toward the teacher beginning to be more open up and trust her students' ability to perform their own learning, since she did not control every single step as before.

Throughout the semester the teacher encouraged students to seek and value alternative modes of investigation or problem solving; this emphasis appeared constantly from June through the end of the semester. For instance, when asking a question, she attempted to ask at least two students the same question as she thought they might reply with different answers and it was possible that some of their ideas might be points that the other students or even she had not known. Kamonwan clarified to her students that each of them could arrive at the same answer using different solutions. One of the activities she conducted in June elucidates her intention to encourage students to think alternatively. In that class, the teacher divided the students into two groups. The first group used a graph to solve a problem while the other group started solving the problem using a formula. Her purpose was to help students to discover that they could end up with the same answer using different methods. She told the class, "In this problem, there are two ways to find the answer which are drawing a graph and using a formula" (Kamonwan: FO, 6/12/12). This was an example where she encouraged the formal presentation with exploration, which made the students realize that they could use alternative modes to solve the problem. When asked her reason for conducting this activity, she responded, "I want them to think more that there is not only one way to solve a problem. Each of them can use a different method but we can all get the same answer" (Kamonwan: LI, 6/12/12).

A few weeks later, the teacher continued her class with a graph interpretation activity in which the students worked in groups and practiced drawing graphs.

Kamonwan continued to creatively approach her lessons by assigning the students to find a linear equation; she asked the students in Group 1 to start from the formula and plot a graph while the students in Group 2 started from a data table. However, at this point in the semester the teacher still concluded the activity by summing up its significant outcomes for her students. On the same day (6/22/12), Kamonwan continued an investigating activity called Mr. Xavier (Norton-Meier, Hand, Hockenberry, & Wise, 2008), which was meant to introduce students to an investigative learning technique that she had learned from the ABI workshop. She said, "I think [this activity] is good because it helps the students to think about reasoning, claim, and evidence." (Kamonwan: LI, 6/22/12). Kamonwan indicated that she applied this activity in order to employ some steps of the SWH approach to this class. She explained, "I haven't started with the first step which is questioning. What is my question? I will try this step later. I think it is better to adjust gradually." (Kamonwan: LI, 6/22/12). She also provided the feedback that her students not only enjoyed this activity but also started to argue about the ideas and asked questions to the group such as, "How do you know that the mirror is broken?" (Kamonwan: LI, 6/22/12). These types of questions encouraged other students to support their ideas with evidence. Ultimately, this negotiation resulted in a positive learning experience for the whole class; as Kamonwan noted, "Everyone had different ideas. But finally, we discussed those ideas and ended up with a group consensus." (Kamonwan: LI, 6/22/12). She furthermore stated that she planned to continue to apply this procedure in her class; as she said, "I think I may apply this strategy to my next experimental lesson. For example, when doing this experiment, they can think, 'What is my question?' 'Why did I do this?' 'What evidence can I use to support my answer?'" (Kamonwan: LI, 6/22/12).

In addition to encouraging her students to seek alternative modes of investigation, Kamonwan attempted to create diversity activities in each of her classes. For example, in a class on July 7th, she aimed to evaluate students' understanding of the concepts of 'force and motion' by asking them to apply the five equations of motion in Physics they had learned in the previous class to a problem-solving scenario. The students were assigned to work in groups, and the teacher added a peer reflection session to the activity by asking each group to comment on the answers of the other groups. Then the students returned to their own groups to discuss the comments they received from their peers. After this the teacher asked the students to "Look at your friends' comments and compare them to yours. Do you still confirm your answer? Or do you want to change it?" (Kamonwan: FO, 7/7/12). At the end of the class, she requested that the students present their conclusions. During the presentations, one of the students said, "Our group decided to use 's = ut + 1/2at2' with this problem. The first comment suggested another formula but we thought it would be better to stay with our original idea." (Kamonwan: FO, 7/7/12). Even though the group did not offer a very clear explanation of why they though their idea was more practical than the one that had been suggested, this event does illustrate the beginning of students' attempts to critique and negotiate ideas. With this activity, the teacher was able to promote several skills, such as problem solving, critiquing, and communicating.

Memorization—such as memorizing the International System of Units (SI)—was another point the teacher often emphasized in her class, particularly in the beginning of the semester. Kamonwan kept reminding her students that, "When taking an exam, I won't provide you with a formula. So, you have to memorize all the formulas for yourselves" (Kamonwan: LI, 5/25/12). However, later in the semester the teacher shifted her focus, encouraging students to spend less time on memorization and more time on knowledge construction. She told them,

> You guys are familiar with learning by memorizing and with the way that teachers feed you the information; this makes you not have to think. I can easily give you an answer but when I do that you do not have to think. I would rather have you understand the ideas more deeply and be able to apply your knowledge

> about Pythagoras and Trigonometry to solve this problem. That way, you will learn where the answer came from (Kamonwan: FO, 6/1/12).

The shift in the teacher's focus away from memorization is supported by the fact that its role in her class steadily decreased in June. This is illustrated by an activity Kamonwan conducted to help her students understand where 'sin, cos, tan' come from in which she clearly told her students, "This is the way to get 'sin, cos, tan.' You will learn this with understanding, which is better than memorizing it" (Kamonwan: LI, 6/19/12). Throughout the activity, she encouraged the students to realize the importance of discovering the source of the knowledge instead of just memorizing it, as this would be useful when they studied at university levels. The teacher encouraged the students to discover the concepts using a one-unit circle. Then the class concluded the activity together and finally found the relationship of 'sin, cos, tan.' This activity revealed that the teacher was paying attention to students' knowledge construction; instead of quickly explaining the concepts in a few words or offering a formula for the students to memorize, such as "sin 30° is equal to cos 60° or sin 30° = ½," as she normally did, this time she decided to have the students explore this idea by themselves before the formal presentation. The result was that the teacher encouraged the students to place more emphasis on how to get the answer and the source of the information than on what the definitions the concepts was. She said, "You don't have to remember the formula, such as 'v = s/t.' Rather, you would do better to know where it came from" (Kamonwan: FO, 7/24/12). When reflecting on this activity with the researcher, Kamonwan noted that,

> I tried to encourage them to discover the source of the formulas by themselves. They should know where and how these formulas were derived. During the class, when I walked around, I heard the students discussing this with one another, saying things like, 'It should be this…this… We should use this. Can we use this formula instead?' They argued the ideas until they got a group consensus (Kamonwan: LI, 7/24/12).

Throughout July and August the teacher put more effort into engaging her students as participants in the lessons by doing things such as encouraging the students to predict what was going to happen before conducting an experiment. However, at the end of each class the teacher still summarized the concepts and made sure that all of the students understood them before the class was dismissed. This continued into August, where due to time constraints that left the class no time for experimenting, the teacher prepared the data and assigned the students to freely design graphs that they thought would adequately explain the data. While this allowed the students more freedom over their learning, the teacher still walked around the classroom and guided the groups in the correct way to finish this task. Thus, it appeared that the teacher was working to lower her role from 100% lecturing to gradually becoming a facilitator; rather than simply feeding students the answers, she worked to explain things to them by asking probing questions. For example, when a student asked her whether an answer was correct, she did not immediately respond, but instead encouraged him to figure it out on his own. She said, “I don’t know. Think by yourself. Do you want to try throwing the rock again?” (Kamonwan: LI, 8/10/12). Kamonwan also continuously emphasized to her students that “Anytime you give an answer you should have evidence to support it,” and she promptly encouraged students to elaborate their answers with reasoning by saying, “Do not only provide me and your friends with the answer. You have to explain more” (Kamonwan: FO, 6/1/12). The students noticed their teacher’s changing pedagogical method, mentioning that Kamonwan enhanced the student-centered learning approach by pushing them to think. They said, “If we cannot solve the problem, she will come to guide us. However, we have to think first. She just guides us but does not give us the answers” (Kamonwan: SI, 8/31/12).

Learning Environment

Kamonwan reflected that ideas from the ABI workshop initiated her attempts to allow more time for students to talk in class. She explained, “At first, I learned the idea from the workshop. Then, I tried to implement it in my classroom. Everything is going well. Now the students won’t allow me to move on. They say, ‘Wait for me; please give me more time to think. I haven’t finished yet’” (Kamonwan: RI, 8/10/12). The teacher reported that her students seemed to have become more familiar with the new leaning approach and they now preferred to think first rather than just waiting for her to suddenly give them an answer. One month after adopting the ABI learning approach, Kamonwan said that she noticed her students beginning to negotiate in class. She said, “I have found that students are starting to negotiate within their groups. Furthermore, I have noticed that the students can defend their ideas and persuade their peers to agree with their claims” (Kamonwan: LI, 6/12/12). She also explicitly stated that her students had improved on their confidence in sharing their ideas in public; “They are better at sharing ideas. At first, I was worried. But now they are improving. Now they talk more. Some of them who didn’t like to talk have now started talking” (Kamonwan: RI, 8/30/12). The teacher commented that this change might have occurred in part because of her stress-free classroom environment and the fact that she did not criticize students for incorrect answers and actively promoted that other students behave in the same way.

Group work was another feature of most of Kamonwan’s classes, and she used it to promote student discussion during her activities. For example, when talking about the relationship between velocity and time, she required the students to discuss their conclusions within their groups. She also reported that learning in groups helped the students to understand the concepts better since at times they understood each other’s explanations better than hers. While the students worked in groups, the teacher usually walked around to see if they had any questions or needed her assistance. The teacher and students also often did collaborative learning such as interpreting and analyzing motion graphs together. As Kamonwan continued to encourage the students to learn in groups, it became evident that they were becoming familiar with this way of learning, and that that encouraged them to discuss ideas with their peers. For example, while comparing their drawings one of the students asked, “Is your drawing the same as mine?” (Kamonwan: FO, 6/10/12). This action occurred without the teacher’s reinforcement. The idea of group work was also useful in the students’ opinion. They stated, “Sometimes the teacher explains things very quickly. But the group work is good. We can ask friends whatever we don’t get from listening” (Kamonwan: SI, 8/31/12). At the end of the semester Kamonwan reflected on her satisfaction with promoting students to be active learners; she mentioned that both she and her students had changed as a result, explaining, “When we use this approach and ask them to work in groups, I observe that most of them more actively participate in class activities. The number of students who do nothing is decreasing. Overall, I think my students love to think more than in the past, when they just listened and waited for my answers” (Kamonwan: RI, 8/31/12).

In addition to group work, Kamonwan established a gallery-walk activity where she asked the students in each group to draw their answer on a poster board and place it around the room. Then, she provided time for the children to walk around so that they could talk with other groups and learn from each other’s ideas. During this activity, the students actively discussed the points that were different from their own answers. Kamonwan reflected that by doing this activity, “They will learn more, learn from other groups. They can compare their ideas and know how the others think” (Kamonwan: LI, 6/22/12).

Whole class presentation was another learning setting that occurred more often as the months progressed. Interestingly, the teacher was not the sole source of this improvement to the classroom learning environment; it also occurred because the students were developing their communication skills and thus began to present longer explanations with reasoning and to use evidence to support their ideas. For example, in one of the classes in August the teacher asked two students who had different ideas to perform their solutions on the white board together. She mentioned, “They both got the same answer—the distance is equal to 120 m—even though they used different methods to solve the problem” (Kamonwan: FO, 8/14/12). She then asked these two students to discuss what they had done and to involve the other students in that conversation. Even though the discussion was not as rich as it could have been because it was short and the teacher still played a key role in leading it, it was clear that the students’ voices were growing. This example also shows the teacher’s ability to replicate the learning environment in various settings; she began by encouraging discussion in small groups and then brought the interesting points or conflicting ideas into a large group setting.

Kamonwan also tried to adjust her classroom environment to include more communicative learning such as peer reflection activities and group work that motivated students to share ideas. In order to encourage students to discuss and ask questions during these activities she often asked, “Does anyone think differently? Who wants to add an idea? I hear you are arguing. Try to defend your ideas andgain the support of your group” (Kamonwan: FO, 7/31/12). Kamonwan noticed that the students reexamined their ideas after negotiating with peers. She mentioned, “One of my students said that she disagreed with the group’s idea. But after her friend explained it to her she told me that she changed her mind. After negotiating, she was able to see that her idea was not accurate anymore” (Kamonwan: LI, 7/3/12).

The teacher also tried to encourage her students to communicate their ideas in front of the class via presentations after group work. At the beginning of the semester this had not been the case; during presentations the students simply wrote their answers on the white board with little or no discussion. However, later in the semester the teacher would ask them to verbally explain their written demonstrations. She then tried more to involve the other students by encouraging them to ask questions of the presenter and to argue about conflicting ideas. Even though communicative learning was still not flourishing at this point, the students were more actively participating in class activities and the proportion of students' talk was also increasing. The students noted this as well, saying, "I think we have a lot of chances to discuss with friends. I was not familiar with this way of learning, so I still feel nervous sometimes when [the teacher] asks me a question." (Kamonwan: SI, 8/31/12). Another student commented that, "Instead of just staying with our own ideas, hearing from the others also opens our view. It is not just our idea that is always right; others may have a better one" (Kamonwan: SI, 8/31/12).

By the end of the semester Kamonwan saw that her classroom environment had changed to a place where every student was free to talk or ask questions, which may be different from other classes where teachers did not provide time for discussion. She revealed, "I am fine when students dispute me. We can definitely talk. Some teachers don't accept when students say something incorrect, which makes students afraid of expressing their ideas or talking in public" (Kamonwan: LI, 6/22/12). In her class, she also created a climate of respect where students could say anything without fear of ridicule. She announced in class that "If students in your group have different ideas, please come outandshare sowe can compare the ideas. Don't be afraid of presenting a wrong idea. We can share and fix it" (Kamonwan: FO, 7/31/12). Kamonwan additionally reported to the researcher that, "I always encourage them not to stop thinking. However, today there were still two students who asked me, 'Teacher, what is wrong with my answer?' I told them that it is okay. They will learn from that mistake. It is better for them to share a wrong answer than for them to never learn why it is wrong" (Kamonwan: LI, 7/13/12). This makes it clear that the teacher fostered her students to learn from their mistakes. For example, when students made a mistake about drawing an arrow while solving a problem, she said, " This isacase study for all of you. Next time, be careful when using an arrow to represent the problem" (Kamonwan: FO, 8/24/12). She also praised students when they did well in class, reinforcing their efforts by saying things like, “See! You guys are excellent. Even though I didn’t tell you what to do, you could do it by yourself” (Kamonwan: FO, 8/24/12).

Kamonwan also reflected that promoting students’ negotiation helped her to see whether “my students actually learn in class since in the past I just taught them but didn’t even know if they were following me” (Kamonwan: LI, 7/3/12). In later months, she tried to add negotiation time to her regular problem solving activities. She reported, “Now I provide more time for them to analyze and discuss the solution of the problems” (Kamonwan: RI, 8/31/12). She felt that this type of discussion suited physics learning well, commenting, “There are several ways to teach physics. For instance, in this class we don’t always do an experiment. We may just discuss the topic instead” (Kamonwan: RI, 8/31/12). She further compared her current teaching with her previous teaching, which had relied more on the textbook; she said by learning in this new way, the students got more opportunities to brainstorm ideas because everyone was required to participate in the thought-provoking activities. Kamonwan was very satisfied with her new style of teaching; she informed the researcher that she had prepared a lot and tried to adjust her teaching by finding new techniques to make the students enjoy learning. Again, she tied the advantages of this shift in her teaching to her particular subject matter, saying, “I apply several techniques, because in physics, we cannot just use one technique since it won’t work in every situation and the students will get bored” (Kamonwan: LI, 7/27/12). Rather than relying solely on the textbook, the teacher had now come to believe that conceptual understanding should be stressed in the classroom, and that “tutoring should be on other time. We can create a tutoring program but it should be separated from class time” (Kamonwan: RI, 8/10/12).

Sutisa

Sutisa was the final of the three teachers who were classified into the shifting group. Compared with the other teachers in this group, she changed the least in terms of teaching practice.

View of Learning

Sutisa defined learning as the process of gaining knowledge, explaining, “It is not necessary that we have to learn only in a classroom. We can learn whenever and wherever we are, even in the office, home, or school or while reading a book no matter what the topic is” (Sutisa: RI, 5/25/12). She believed that in order to learn physics or any other subject well learners needed to love it first. She said, “If you start with loving it, you will be able to work with it more at home. But if you start with hating it, it is difficult to achieve in learning. This is an important point. Also, the teacher is just a part of the learning process. If children don’t like a teacher, they don’t learn well” (Sutisa: RI, 5/25/12). Therefore, she had tried to create a stress-free classroom where students enjoyed learning. She also attempted to understand the needs of children this age, pointing out that, “We cannot stop every one of their behaviors, such as chatting in class. We should admit that it is children’s nature to do this. Thus, it is impossible to expect them to be quiet all the time. I try to manage the environment in my class so that all students can be relaxed in learning” (Sutisa: RI, 5/25/12). She pointed out that learning without stress was important to her, saying, “For me, if I learn with stress, I cannot learn well. Too much tension is not always good. It is better to relax sometimes” (Sutisa: RI, 5/25/12).

The teacher emphasized that the most important component of learning was that learners should be able to “catch the main point about what the teacher has taught. They have to be able to evaluate themselves. They actually don’t have to get everything that the teacher taught twenty five percent is enough. But they have to go back and repeat it at home; then they will get more out of it" (Sutisa: RI, 5/25/12). Sutisa commented that to learn physics well students should not study alone but rather should work in groups because they could help each other clarify any points that were unclear. She wanted her students to be able to construct their own explanations and convey these to their friends, believing that this would help them to better understand the concepts. She said, "Explaining to their friends, that is the way they can improve their knowledge because while explaining learners have to think and use reasoning. When giving reasoning, they have to refer to a theory. Then when the friend asks a question, they have to think of how they should answer" (Sutisa: RI, 5/23/12). The teacher further explained, "From my own experience, when I was young I couldn't understand the content well while just listening to my teacher. But when I became a teacher, I had to explain to others; this helped me understand the concepts more deeply. So, I think the students can also learn better while explaining ideas to their friends" (Sutisa: LI, 6/27/12). It is not surprising, then, that when asked her opinion of 'learning by negotiation,' she commented, "There are many ways to learn science. Negotiation is one of them and it helps students to understand the concepts better" (Sutisa: RI, 8/31/12).

The teacher believed that the overall process of learning should involve providing information as well as constructing knowledge. She stated, "They should do well in both receiving and giving knowledge. Transferring knowledge shows their understanding. Because when we discuss things with our peers, we have to negotiate ideas. So, it is time for them to practice thinking and conducting reasoning" (Sutisa: RI, 5/25/12). Sutisa further mentioned that it was not necessary that the teacher always be the person who provides information; she suggested that learners could also gain knowledge by themselves via reading or seeking information from other sources. As time passed, she affirmed this view of the meaning of learning, commenting, "It is the way we seek information. Whatever passes through our lives, no matter whether in the classroom or outside, is all learning" (Sutisa: RI, 8/31/12). The teacher still emphasized the importance of students' positive attitude in learning; what changed was her expectation that they think scientifically—that they should be able to ask questions, conduct their own research, and communicate knowledge to others, rather than just keeping it to themselves. However, she still confirmed that the teacher should provide information to students first because "giving knowledge will help to guide them to be able to construct their own knowledge. We should provide them with a theory and then ask them to apply it. We may have to demonstrate an example of how to solve a problem and then let them do it by themselves in the next step" (Sutisa: RI, 8/31/12).

The importance of guiding the students through the learning process was something that Sutisa mentioned throughout the observation period, though her view of what that meant grew over the course of the semester. At the time of the first interview, she explained her role as a guide through the students' learning process, saying, "My role is to guide them and to ask them to work by themselves" (Sutisa: RI, 8/25/12). Later in the semester, she added to her concept of the teacher's role in promoting students' knowledge construction, mentioning that, "I would ask them to learn in groups. Through group work, they can start forming questions, start thinking of how to answer their peers' questions. I think this is the method I will use to promote their knowledge building" (Sutitsa: RI, 8/31/12).

Even though this teacher had a positive attitude toward student-centered learning, she also mentioned her difficulties with promoting this approach, especially during the final months. Sutisa said time was a barrier to her ability to conduct investigation activities in her class. For instance, one day she revealed that, "The reason we didn't do the experiment today was because we ran out of time. If we had done the experiment, it would have taken a whole period" (Sutisa: LI, 7/13/12). She informed the researcher that if there was enough time, however, she would prefer her students to design and work on investigation activities in groups. She further said that she could not provide many activities involving students during July and August because she needed to finish up all topics before the upcoming final exam. This might be one reason that her performance scores declined in later months.

Despite the time barriers, Sutisa continually emphasized the importance of cooperative learning where students interacted with each other. However, she mentioned that sometimes not every student collaborated in her activities. She said, "Cooperative learning is a good strategy. I usually use it but there are some students who do nothing. They don't think; they just wait for my answer. For example, there are five students in a group but just three of them are working while the other two are just being quiet. However, I cannot force them to interact" (Sutisa: RI, 5/25/12). The teacher also mentioned a few times that she was curious why students who did well while participating in class activities sometimes scored low on tests. She said the students told her "they were excited. Also, they said they couldn't complete all of the questions on time. They actually are good in class but the feedback from the exam is not what I expected" (Sutisa: LI, 7/27/12).

Some of the differences between in-class and test-based success may have arisen from the students' widely varying learning goals. When asked what they expected from this teacher's physics class, some of them said their purpose was to understand physics concepts. However, one student responded that 10th grade should provide a basic education for his future learning; thus, he said, "I want to be able to calculate." Another student replied that physics was challenging and she wanted to "see how much I could do" (Sutisa: SI, 8/9/12). Even though the students seemed satisfied with Sutisa's new teaching approach, they still expressed the need for skills other than understanding a theory and problem solving practice; for instance, one student said "When I go to the tutoring center, they emphasize the formula shortcuts. So, I want the teacher to help me on this. This would help us a lot when we take a competitive exam. It would help us to think faster" (Sutisa: SI, 8/9/12). When discussing this issue of student preoccupation with grades and the national education test, which was a common problem for many Thai teachers, Sutisa stated that she was sometimes concerned but still believed that promoting students' thinking processes was more important than worrying about grades. She expressed that, "Other than looking at students' grades on an exam, I also think about their performance in class. If in class I ask a question and they can answer it, that means they understand. I will look at both grades and performance in class" (Sutisa: RI, 8/31/12). Despite others' emphasis on grades and tests, Sutisa would "rather have them focus on the procedure than on the answer, because they are going to use this knowledge with other subjects and in their daily lives too, not just in physics class. I will continue student-centered learning with my other classes too" (Sutisa: RI, 8/31/12).

However, the teacher pointed out that the difficulty of conducting student-centered learning was that "The students sometimes could not think. Thai students are unlike American students who can learn by themselves after learning a theory. Our children still cannot do that." (Sutisa: RI, 8/31/12). The teacher commented that her students only asked questions a few times. She said this was because of the nature of Thai students in that "They just like to sit and listen. They don't have questions even about whether they understand or not. I also don't understand if their lack of questions means they don't know or already know the answer but just don't want to say" (Sutisa: RI, 8/31/12). However, she commented that in order to solve this problem "At least we have to make them feel less depressed in class by becoming familiar with their teacher and peers. Then, they can feel good about asking questions" (Sutisa: RI, 8/31/12).

Sutisa further indicated that this was not about the students' ability, but occurred instead because "The Thai people's nature is to listen more than to share ideas and to feel afraid to be ridiculous when saying a wrong answer in front of their friends. They don't like to talk and don't like to think outside the box" (Sutisa: RI, 8/31/12). Despite this, she suggested that,

> We have to teach them how to think and how to ask questions. Dare to ask. They normally think what the teacher said is correct. So, that's why they have no doubts. They may be afraid of answering incorrectly and of getting blame from the teacher; that is why they don't know the answer. We should fix this. We should start when they are young (Sutisa: RI, 8/31/12).

<u>Teaching Practice</u>

Figure 4-6 illustrates that Sutisa showed some improvement on every observed criteria after she had been introduced to the ABI approach. Nevertheless, she struggled to maintain her shifting practice, as evidenced by the fact that her scores dropped in the third and fourth months of observation. However, even though her scores dropped in these months, they were still higher than in the first observation.

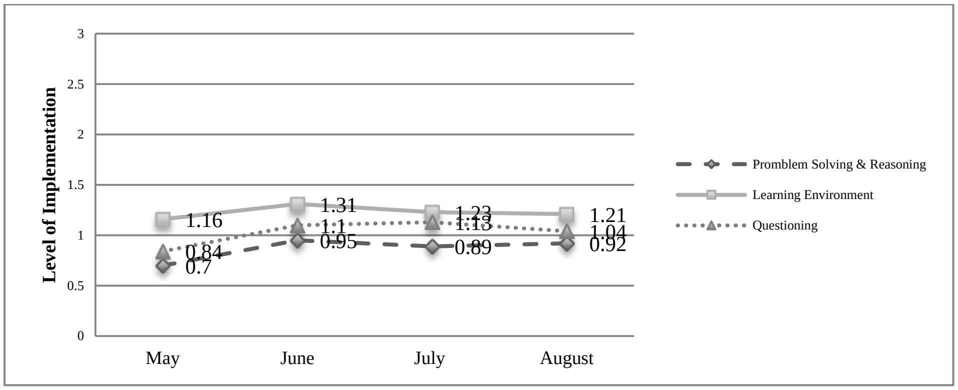

Figure 4-6 Sutisa's Level of Implementation of the Observed Criteria

Questioning

Sutisa mentioned that questioning was very important in learning science. She indicated, "The effective questions are the ones that promote students to think. In my class, I also use follow up questions because sometimes one student cannot provide a correct answer. Then, I have to ask the others to add ideas and combine all the answers. We cannot expect that the answers can be delivered completely just by a single student"

(Sutisa: RI, 8/31/12). According to figure 4-7, the teacher's questioning increased every month. In addition, the teacher maintained her use of medium level questions, which were used the most in each month of the observation.

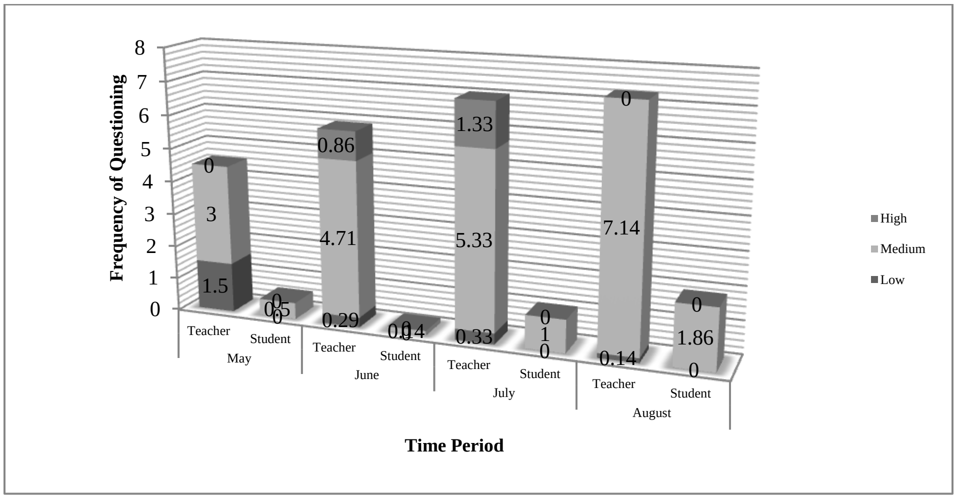

Figure 4-7 The Frequency of Questioning used in Sutisa's Class

Based on the researcher's field note observations, the teacher started her first month with a small number of questions and normally looked for an exact simple or short answer such as "What is the unit of time that you know? How many days do we have in a year? If I ask how many hours are in a year, how do you know?" (Sutisa: FO, 5/23/12). But in later months the teacher developed her method by asking more probing questions and frequently paused during her teaching to ask if her students were confused about any points. She told the class, "If you don't understand, raise your hand. You can ask your partner first, or ask me. I will give you a moment to ask questions" (Sutisa: FO, 8/31/12). Sutisa thus used questioning to engage her students with the lesson or to encourage them to make predictions before exploration. For example, she asked, "Look at the Vernier Caliper. What do you think it can do?" A student then answered, "It measures length."

Another student said, “It measures depth” (Sutisa: FO, 6/8/12). She also motivated her students to engage with the material by expecting them to construct their own questions, commenting that some of the students’ questions were interesting; for example, “Why don’t we use 1/50 to represent time instead of 3/50?” (Sutisa: LI, 8/8/12) and some brought up points that she sometimes had not even thought of before.

These questioning techniques were particularly useful as a tool for engaging and stimulating quiet students to participate in her class. When Sutisa noticed that students were quiet in class, she encouraged them to actively participate in activities. For instance, she would announce, “Everyone should have a question after listening to your friends’ presentation” (Sutisa; FO, 8/15/12). Sometimes she offered bonus points to a student who asked a question; for example, “I will give you one point when you ask one question” (Sutisa: FO, 8/1/12). The researcher noticed that as a result of these practices, students started to ask questions of their group members. For instance, one student asked, “Can we use another formula to solve this problem? How many other formulas can we use?” Then another student responded, “No. We can only use this one due to the conditions given in this problem” (Sutisa: FO, 8/1/12).

Sutisa not only used questioning to assess students’ conceptual understanding or to engage them in learning, but also to promote critical thinking skills, such as when she inquired, “If you jump from a moving train, what should you do to avoid falling on the ground?” A student then answered that he should keep running and then try to gradually slow down his speed rather than suddenly stopping” (Sutisa: FO, 8/22/12). Or she would sometimes ask questions that aimed to enhance students’ elaborative reasoning; she told the students that she did this because “I want you to practice giving me a reason. It doesn’t matter if the answer is right or wrong. I just want you to share your ideas” (Sutisa: FO, 5/30/12). To support this practice, many times Sutisa would not suddenly answer a student’s question but would instead ask them to look back to the result and try to think more until they could come up with the answer.

The teacher explicitly told the researcher at the end of the semester that she thought she had changed because “I use questioning more and I can wait longer for them if they have questions for me” (Sutisa: RI, 8/31/12). Not only had she changed, but the students had too. She stated that even though this change was not as noticeable, “Compared to the past and with other classes, I think they ask more questions” (Sutisa: RI, 8/31/12). The results shown in figure 4.7 could support this claim; it can be seen that the number of student questions noticeably increased at the end of the semester. Mostly, the students asked questions related to a problem’s solution, such as, “How can we find the velocity of this car? Should we use the same velocity when this car is starting to move?” (Sutisa: FO, 8/1/12).

Problem Solving and Reasoning

Sutisa promoted using alternative modes of thinking while solving problems. She told the class, “You can find the slope and the constant number by either using a graph or calculating it from a formula” (Sutisa: FO, 6/27/12). In another example, she encouraged students to find the acceleration by using several equations. When asked why she focused on this idea, she explained, “I want to hear alternative ideas from them. Also, I want them to see and consider how their ideas are different or similar” (Sutisa: LI, 7/27/12). The teacher also tried to come up with several thought-provoking activities to enhance student knowledge construction, such as asking students to interpret several graphs in order to practice elucidating their meaning.

In addition to encouraging students to play a more active role in the classroom, Sutisa sometimes even allowed them to learn by themselves, and reflected that this was a result of changing her teaching methods. She reported, “Previously, I explained first, maybe because I had to take care of the instrument and thus had to teach them first how to use it. Then, I would let them work by themselves. But in this class, I allowed them to learn without any explanation; I let them learn from the sheet and practice by themselves”

(Sutisa, LI, 6/13/12). The teacher commented that after attending the workshop she decided to change some of her methods; "I started the class by asking them to read my sheet first and then asked if they had any questions. Previously, I would summarize the significant points for them after they were done reading. But not today; today, I asked, 'Are you done reading? Any questions?'" (Sutisa: LI, 6/1/12). Sutisa mentioned that even though this process took more time, the students seemed happy learning this way. She said, "I normally can finish one topic within one hour, but teaching this way it takes about two hours. Instead of giving them time to ask questions, I could simply give them the answers. This would allow me to finish the lesson in a shorter time, but I also would not be sure if they really understood the lesson. On the other hand, by learning this way students are happy and relaxed" (Sutisa: LI, 6/1/12).

Sutisa mentioned during one of her July interviews that she was currently behind schedule and needed to hurry up her teaching. However, she did not skip the investigating activities. For example, she still conducted the experiment about acceleration using the 'Ticker Timer Tape,' although she decided to shorten the process by preparing a paper with the data she had completed outside of class so the students could analyze the data in order to find the distance and time of the object. This revealed that even despite time constraints, the teacher still offered opportunities for student investigation as time permitted. She then helped her students to understand the topic more deeply by drawing several pictures and asking them to describe how displacement varies with time, focusing on both the concept and the mathematical description. Sutisa also required the students to practice drawing graphs in order to represent the object's motion based on the data they had. And at the end of class, they had a discussion about the factors that affected the object's acceleration based on the results of the class investigation. Despite using these methods, however, this class was not an example of an entirely inquiry-based classroom since the teacher still offered some information for students, such as demonstrating how to represent the data in graphic forms, and still played the role of summarizing the main concepts, rather than letting students conclude them for themselves.

In August Sutisa's class continued to shift in the direction of student-centered learning. While observing group work in one of her August classes, the researcher heard the students brainstorming ideas and designing how they would communicate their solution to the class. They said, "We should use yellow to represent our solution and green to represent the answer and use various colors to draw a picture of the moving car" (Sutisa: FO, 8/1/12). During this observation, it seemed that everyone in the class was actively participating in the activity in various ways; some were listening, some were sharing ideas, and some were drawing their answer on a poster paper for their group's presentation. When reflecting on their own performance and participation in this activity, the students commented that "We talked in groups about the solutions. We divided the responsibility to present to the class." When asked what they had learned from this activity, the students answered that they had gotten "Practice to think. Practice to express our ideas" (Sutisa: SI, 8/9/12).

In order to help the students visualize real examples of ideas, the teacher usually brought in several materials, like glasses and Ping-Pong balls, on which they could practice using Vernier Calipers and micrometers to measure the objects' scale (Sutisa: FO, 6/27/12); similarly, she used a sand bag to represent the 'Free Fall' concept (Sutisa: FO, 8/8/12). The result of these techniques was that in June students started to discuss what they were doing in class. For instance, the teacher asked her students to discuss the number they could read on the materials' scale (Sutisa: FO, 6/27/12).

Sutisa also employed divergent modes, such as graphs, pictures, and diagrams, in addition to her explanations to help her students imagine complex theories. For instance, she illustrated a head-to-tail vector to graphically find a vector sum. Furthermore, she encouraged the students to do the same thing, using modes to represent their ideas. Then she asked them to present their ideas to the class, saying, "Come out to explain your solution to your friends. You might have a different solution, so the rest can compare and pick which way is easiest and make sense of things for themselves" (Sutisa; FO, 6/27/12). The researcher noticed that there was also some shouting from the audiences while the presenters expressed a wrong answer.

The teacher, in fact, usually encouraged her students to think. She would tell them, "Don't wait for me to give you an answer, you have to practice thinking or else you won't get anything from this class" (Sutisa: FO, 5/25/12). She further mentioned, "I am not interested in the answer as much as in the procedure" (Sutisa: FO, 8/31/12). However, even though promoting students to think was occurring more often in her class, she still focused on memorization skills and encouraged students to memorize information like the number of 'sin, cos, tan' or scientific units like the candela (cd), which is the unit of light intensity, because she believed that it would help the students while solving a problem. The teacher also taught the students a trick to help them remember the numbers of 'sin cos tan' which she called the 'hand trick.' She said, "This is what you have to remember since it will be useful for you while solving a problem" (Sutisa: FO, 6/22/12).

Nevertheless, in later months the teacher more often focused on getting students to think about the source of information, such as where a formula came from. She said, "Some of you might not see the importance of knowing where a formula comes from. It is actually critical since it will help you to understand the theory more deeply" (Sutisa: FO, 8/1/12). The students, at the end of the semester, reflected on their teacher's teaching that "She is continuously improving because on our first test students got low scores. So, she uses a variety of strategies to improve our understanding such as finding various problems for us to practice on"; another student added, "She lets us work in groups" (Sutisa: SI, 8/9/12).

In addition to assessing students' conceptual understanding with tests, Sutisa liked to ask them to reflect on their learning at the end of classes. She would ask things like, "What's wrong? Do you know why you did the last question wrong?" (Sutisa: FO, 6/1/12). By doing this, she explained, "I want them to reflect on why and how their answers were wrong. In this case, they know that they were wrong because of their mathematical calculation. Thus, they got to improve on this" (Sutisa: LI, 6/1/12). Then she also asked the students to re-summarize those ideas in their notebooks based on their own understanding. In terms of reflective learning, the students affirmed that their teacher often asked them, "'What did you learn from this lesson?' This gives us an opportunity to ask questions, talk, and summarize the ideas by ourselves about what we have learned." They mentioned that at first they were nervous when she asked this kind of question but "Later [we] prepared more since [we] knew that she would ask us" (Sutisa: SI, 8/9/12).

Learning Environment

Learning environment was the observed criteria on which Sutisa earned the highest score on her teaching practice. She emphasized 'peer-to-peer learning' in that students interacted with each other in order to promote conceptual understanding or to accomplish the class's investigation. She told the class, "Please explain things to your peers in your group. Help your friends who do not yet understand" (Sutisa: FO, 5/25/12). Thus, group work and student discussions were component of the learning environment setting that occurred often in her class. Sutisa reflected that other than improving her questioning skills, she developed her establishment of the learning environment. She stated, "Previously, I didn't emphasize group work very much; rather, I focused on whole class learning" (Sutisa: RI, 8/8/12). When asked the reason for this change, she indicated that it was because "I want to know whether learning this way can help students to better understand the content" (Sutisa: RI, 8/8/12). In Sutisa's opinion, group work could also reveal students' ideas via discussion and could promote collaborative learning where they shared and helped each other to clarify their conceptual understanding. This action corresponded to her view of learning; she repeatedly said in the reflection interviews that students who could construct explanations and describe ideas to their friends were smart since these actions showed that they understood the concepts well. Furthermore, Sutisa said that this process not only ensured that students had a chance to practice answering their friends' questions and to figure out a way to explain the concepts, but also that they could hear from their friends whether their ideas made sense. She explained, "Most of the time I ask them to work in groups. It is good for them to discuss and find out that 'Oh, you are right or wrong thinking this way'" (Sutisa: LI, 6/27/12). Sometimes, Sutisa brought issues that appeared in a small group into a large group discussion. For example, she asked students who used different solutions to demonstrate these solutions in front of the class and then asked the rest of the students to decide which one was correct or applicable. She told the students, "Now we will see your friends' answers on the board. We are going to think and discuss together why they have come to the same answer while using different procedures and which one makes the most sense to us" (Sutisa: FO, 7/27/12).

Sutisa attempted to employ these new teaching approaches after attending the ABI workshop. She provided more opportunities for the students to talk, discuss, and present their ideas in various environmental settings including small and large groups. As formerly mentioned, in the second month of observation she asked more questions and waited longer for students' responses, and even though this waiting time was still not very long, an increase in student participation was evident. Previously, the students usually answered questions by reading from the textbook. At that time, this action seemed to be acceptable to her. But after the ABI workshop, she stopped allowing them to use formal definitions taken from the textbook; instead, she encouraged them to speak from their own understanding, saying, "Just think. You don't have to spill the words out from your textbook. Just say what you think" (Sutisa: FO, 6/8/12). Another idea that she added to the class in later months had to do with assessing students' prior knowledge. For example, before starting the 'force and motion' unit, she said to the class "I believe that everyone knows about force. Can you tell me anything you know about it?" (Sutisa: FO, 8/24/12).

In terms of waiting time, at the beginning of the semester the teacher provided only a small amount of time for students' exploration as well as for thinking after she asked a question. For example, when asking, "Is mass the same as weight?" (Sutisa: FO, 5/23/12), she waited just a few seconds for students to think and then she answered how these two terms were different. As time passed, it was observed that the teacher offered a longer amount of time for students to respond to a question as well as provided more time for exploration. However, there were still several times when the teacher answered a question by herself rather than letting the students work on it.

As Sutisa changed her teaching methods, she also noted that her role in the classroom had changed from a lecturer to a mentor. Normally in every class she walked around the tables while students worked on an activity. Furthermore, rather than performing the teaching alone, she sometimes involved the students in brainstorming ideas. She announced, "Let's think together about how many formulas we could use to find this object's acceleration" (Sutisa: FO, 7/27/12). Later, the teacher added student presentations in almost every one of her classes after the students had finished an investigation or group problem solving. The teacher tried to ask the learners to present their solutions to the problems, which mostly focused on practicing the application of physics formulae. Less frequently, she asked them to present their understanding related to a concept. However, the learners did get a chance to explain their reasons for selecting a particular formula to use with a problem. The teacher explained that in designing these activities she "applied some parts of the argument-based inquiry approach from what I have learned from the workshop. I encouraged the students to talk in groups. It was kind of different from other classes that I more quickly when I might sometimes tell them a direct answer" (Sutisa: LI, 8/8/12). It was evident that when the teacher asked the students to present their ideas in front of the classroom, the very first time they seemed to be nervous and described their solution in a very short sentence. But over time they improved and looked more confident delivering their explanations to the class. Also, the class functioned within an increasing climate of respect where the students in the audience listening to those presenting were less noisy and sometimes responded to the questions the presenter asked. Sutisa commented on this class, “I think it is fun and students pay attention more in learning. In other classes, I am not sure if learners really understand if the teacher just lectures. But for this class, I ask them to demonstrate their solutions in front of the class. They also say to me that they understand the concepts I have taught” (Sutisa: LI, 8/8/12).

The teacher claimed that her class was a stress-free classroom; “As you can see, they are not stressed while learning. They are happy. It doesn’t look like they are afraid of asking questions or discussing. It is not that way anymore” (Sutisa: LI, 7/13/12). She often indicated that she intended to establish a non-threatening learning environment, such as when she said, “I won’t force them to sit in groups with the peers they are not familiar with. They are free to select their groups. This can help them to feel relaxed while learning in class. I believe that they wouldn’t respond if they were stressed” (Sutisa: RI, 5/23/12).

It was evident from the researcher’s notes that the students did seem more confident speaking in class. For instance, it was clear that in class discussions the students were confident enough to oppose the teacher or the presenters, such as when they thought their teacher/friends had chosen the wrong equation with which to solve a problem. This might have occurred in part because of the teacher’s encouragement; she always told the students, “You don’t have to feel embarrassed when you are confused or curious. Ask me or ask your friends; don’t let it go” (Sutisa: FO, 8/8/12). When asked to reflect on the nature of her classroom environment at the end of semester, she commented, “The students are improving in expressing their ideas. They have questions all the time. They don’t just listen quietly but rather share their ideas” (Sutisa: RI, 8/31/12). Her attempts to create a stress-free classroom environment were consistent with statements from the students. They mentioned that their teacher was kind and said, “We can ask when we don’t understand.” They further stated, “I feel relaxed. She never blames us when our answer is wrong but rather she explains why” (Sutisa: SI, 8/9/12).

At the end of the observation period Sutisa reflected on her teaching throughout the semester. She said, “I feel that students collaborated well in class activities. This made my class smooth and enjoyable. Students were not bored in my class, and neither was I. I feel great teaching. I also want to hear feedback from the students about how they feel in general and anything they want me to improve” (Sutisa: RI, 8/31/12). The teacher further indicated that this learning environment was occurring due to her changing teaching methods: “Previously, I taught using a traditional style, which is lecturing. Sometimes, I proceeded with my teaching even if the students had no reactions. Now I listen to them first” (Sutisa: RI, 8/31/12). She mentioned that it was not just she who changed her practice, but also the students, commenting, “I don’t have to be strict with them very often now. They look natural. I can let them learn by themselves. At first, we were not very familiar with each other. So I needed to force them to ask questions. But now they just come out from the students automatically” (Sutisa: RI, 8/31/12).

Overall, the teacher was satisfied with her teaching performance throughout the semester and she was impressed with her students’ improvement. She said, “I think the students understand more by learning this way. It is a good learning approach that helps the students to gain long-term understanding, I think. They experience the knowledge by themselves” (Sutisa: RI, 8/8/12). The teacher declared her goal that “I intend to try this new approach with my other classes. I want to see their reactions. It is a good strategy. I think my students really understand the concepts since they can explain when I ask them questions” (Sutisa: RI, 8/8/12). The students also felt positive about learning with the student-centered learning approach. They said, “I like the idea of student-centered learning that allows students to express ourselves because at least we can vocalize our ideas. Then, we can know if they are right or wrong. When using the traditional way of learning, we just keep our ideas in our heads and do not speak them." Another student also supported this idea, commenting, "I like it too since I have a chance to express my ideas. The reformed learning allows us to be open about our ideas. We can say anything." The students then mentioned that their teacher was shifting toward reform-based learning since "I feel excited while learning physics with her. While learning with the original way, the teacher just shows the solution and asks us to just copy the answer. It is different with this new style; we have to think a lot. If we don't think, we can't discuss with friends" (Sutisa: SI, 8/9/12).

However, even though Sutisa asserted her confidence with employing this reform-based teaching approach, she was still concerned and reflected that inquiry may not be applicable in every situation; she pointed out that, "It depends on the topic. Some topics work with this approach but others may not. It depends on the topic, content, time and situation" (Sutisa: RI, 8/8/12). Nevertheless, in the final interview she stated that she felt good trying this approach since it promoted her students to think more, actively participate in class activities, and construct their own knowledge. The teacher then suggested that, "We should start it now. It is good for them. For high school students, it may be a little late. It may be better if we had started this approach when they were in elementary school. If we start when they are little, they will use it naturally. For now, they are growing up, so it is kind of difficult to learn something new. But it is better than doing nothing" (Sutisa: RI, 8/31/12).

The Non-Shifting Group

Even though the teaching practices of the two teachers in this group were placed in different areas—Kritt's teaching was located in the low-medium level while Nattawee's performance was in the medium-low level (see figure 4-1)—the two teachers were similar in that they presented flat implementations of both their view of learning and their teaching practice aspects.

Kritt

View of Learning

To Kritt, learning was about "Searching for new knowledge" (Kritt: RI, 5/24/12) and he maintained this idea until the last interview where he said, "Now my learning is about bringing a new thing to life by using any procedure that makes us know whatever we want to know" (Kritt: RI, 8/28/12). He further mentioned, "I view learning in our classroom as still a traditional process in that students are likely to wait for information from the teacher. However, some of them can learn by themselves and come to ask the teacher when they have a problem" (Kritt: RI, 5/24/12). From the very first interview the teacher emphasized the importance of following the curriculum because "In the end students cannot learn whatever they want; they still have to take the national educational test. This test has its own evaluation criteria, which is the same standard for every student to obtain entrance to a university. Thus, it is necessary that we need to learn by following the curriculum" (Kritt: RI, 5/24/12). The teacher had a positive view of argument-based inquiry learning, explaining, "I think it may be a good thing because when we do an experiment, absolutely we cannot get the exact result as stated in the theory. But if we use argumentative learning, I think it can promote students to think more. It may help them to be reasonable people" (Kritt: RI, 5/24/12). Despite wanting his students to be able to seek their own knowledge, however, Kritt continuously emphasized that this should happen within the scope of the curriculum. Even at the end of the semester, he commented that, "I want them to learn about scientific procedure and the thinking process, and I want them to be able to construct knowledge from their own understanding. Also, I want them to connect physics with their daily lives. However, I have to do this within the scope of the curriculum. The curriculum leads the students' futures because the national educational test is underlined in the curriculum" (Kritt: RI, 8/28/12).

Kritt believed that before promoting students to construct knowledge, it was necessary that the teacher should first provide them with the information. He said, "In terms of teaching and learning, if they learn by themselves without the transfer of knowledge by an expert, learning can hardly occur or will occur slowly or incompletely" (Kritt: RI, 5/24/12). By the end of the semester, however, he had changed this idea, stating,

> Learning through knowledge construction might be the best learning strategy. If we can construct knowledge by ourselves, we know where the knowledge came from and how it was derived. So, we don't need to remember everything because we know its source. Even if we lose it, we still know how we can get it back. Vice versa, if we learn only by absorbing information from the teacher, we know only what it is but not where it came from. When we lose this knowledge, we won't be able to bring it back (Kritt: RI, 8/28/12).

When asked why his answer was now different than in the first interview Kritt answered, "I found if I just transferred information, if I then gave students a test and mentioned what he had learned previously, they could not remember it. With this method, they seemed to understand well at the time I first transferred the knowledge. But in fact, when we brought up this issue to discuss it again, that knowledge was gone" (Kritt: RI, 8/28/12).

Kritt was initially uncertain about reform-based learning. He told the researcher that there were many ways to teach physics in a classroom and it was impossible that one teacher could teach well in every topic. Thus, he preferred to see a good model from an expert teacher. He asked, "Why don't the professional developers or the educators find the best example to show teachers that this is the best way to teach this topic? Then, the teachers will be able to apply or modify this for themselves. I think this is better than asking every teacher to find their own way because this might take five or ten years. I think it is good to see the best example, which may be from the person who performs best." (Kritt: RI, 5/24/12). Kritt strongly believed in this idea, as evidenced by the fact that he mentioned it again in the last interview. He said, "I think it would be good if we can bring the technique from the best teacher of each topic to show the novice teacher so that person will be able to apply it to their own classroom" (Kritt: RI, 8/28/12). Despite his uncertainty about employing new teaching techniques, the teacher mentioned that throughout the semester he had implemented some parts of the inquiry approach. He also explained the meaning of inquiry from his own understanding: "For me, I think inquiry is a procedure to gain basic knowledge or to understand a concept. Students have to find the main idea of a topic by themselves. I think if they understand concepts by themselves, such as how to find the speed, they don't need to remember the formula anymore that $v = s/t$. Also, they can use this knowledge in other situations" (Kritt: RI, 8/28/12).

In his final interview, Kritt commented that Thai teachers and students had been familiar with lecture-based learning for a long time. In addition, he mentioned that the nature of Thai students was to be very quiet since they were prohibited from making noise in class. Thus, they were also afraid of talking or sharing ideas. The teacher suggested that if Thai education wanted to implement this reform-based learning, it was necessary that they started with young learners such as those at the kindergarten or elementary levels. The teacher also mentioned, "It is not just students. Even the teachers, when we go to the training workshop, it is just 2-3% of teachers who talk. The teachers who are quiet, they are still quiet all the time. I think we should gradually change. Students should learn with this approach this year. They might not be familiar with it but when they repeat it next year it will be better" (Kritt: RI, 8/28/12).

The teacher mentioned several times that after being introduced to the ABI approach he was trying to implement it in both of his classes (middle and high school levels). He believed that this approach might be better suited to younger learners than his group of high school students since he thought the contents of physics courses were difficult and left no time for extra activities. He revealed that he was having difficulty designing lessons using the inquiry approach, stating, "For these high school students, it is difficult to apply this approach. I cannot find a way of applying it to my class. I think this is because of the content; physics is difficult. I don't know how to bring this strategy to apply to physics lessons. I think instead it would rather work well for students in middle school" (Kritt: LI, 6/21/12). Because of these issues, the teacher believed that "For high school students, if we use these activities, they will lose focus on their learning." (Kritt: LI, 6/21/12). However, he did think the approach could be useful with middle school students and shared a story of how he had successfully employed it with these students. He said, "I used it the same way we did in the workshop. I emphasized the claim and evidence first. I asked them to design their own investigation and then to negotiate their ideas at the end of class and we figured out the best solution together. I think it worked well with this group of students" (Kritt: LI, 6/21/12). In the final interview the teacher once again confirmed his belief that the ABI approach was more appropriate to younger learners, commenting, "I feel that the 10^{th} graders have fewer interactions because they have been familiar with the traditional learning style. It is difficult to change" (Kritt: RI, 8/28/12).

Teaching Practice

In terms of teaching practice, Kritt's scores in all three observed criteria were low and he consistently maintained this level of teaching without improvement. Figure 4-8 shows that throughout the semester his practices were parallel but flat.

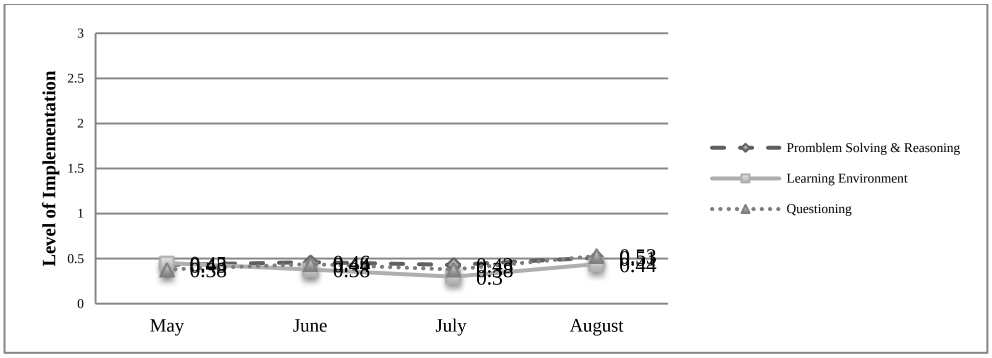

Figure 4-8 Kritt's Level of Implementation of the Observed Criteria

Questioning

From the very first interview the teacher mentioned his belief that students could learn better by questioning. He stated, "If we don't have questioning but just telling, I think just twenty percent of the message will get to the students. But if we have questioning, it is likely to open the door for the students to learn more" (Kritt: RI, 5/24/12). He mentioned that his strategy was to use questioning to assess students' conceptual understanding or to facilitate their problem solving.

According to figure 4-9, however, among the three levels of questioning, Kritt mostly presented medium-level questions, which focused on students' skills in comprehension and application. Additionally, no change was observed in his questioning practices during the study. Kritt reflected, "I think I don't use many questions in class. But I want to ask questions to promote students to keep thinking, questions that are not simple, such as yes/no questions" (Kritt: RI, 5/24/12). He reflected that due to his minimal teaching experience, he did not reach the goal of conducting effective questioning in class.

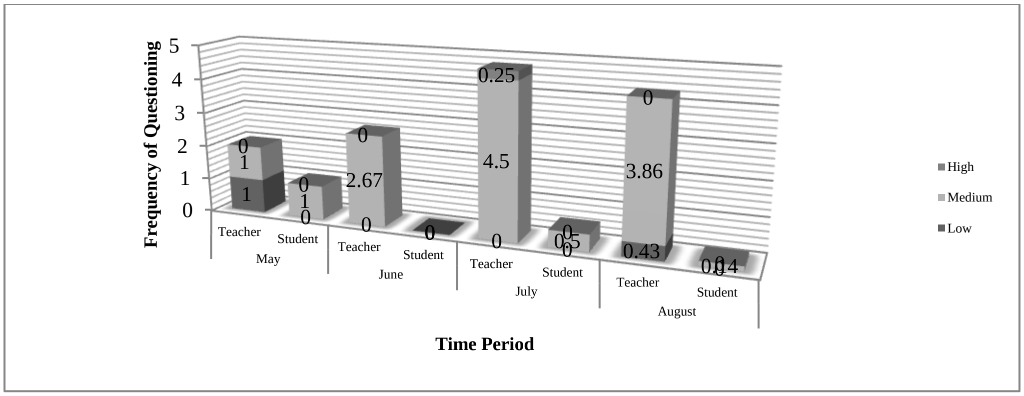

Figure 4-9 The Frequency of Questioning in Kritt's Class

Kritt's assessment of his lack of questioning was supported by evidence from the researcher's field notes, which revealed that the teacher often simply asked for only yes/no or short answer responses. Many times his questions just asked students to explain the meaning of words, as when he asked, "What is science? What is measurement?" (Kritt: FO, 5/24/12). This type of questioning basically required students to recall information or to give him the definition of physics terms such as 'force.' Students would meet the objective of these questions as long as they could reply with a correct definition, no matter whether it came from their memorization of a previous lesson or by reading the passages in their physics textbook.

Most of the questions in Kritt's class were actually presented in written form; very few were verbal because he mostly handed out material sheets with many questions that he aimed for students to answer. However, it seemed that the students did not practice much in class because the teacher typically just demonstrated how to solve a problem on the white board. In addition, many times Kritt simply filled in the answers by himself, without waiting for students' responses. For example, when asking, "How can we find the circumference of a sphere?" (Kritt: FO, 5/31/12) or "Have you ever heard about Trigonometry? What is your understanding?" (Kritt: FO, 6/21/12), he did not provide time for students to think but immediately gave them the formulas to work on. Or when asking, "When saying the temperature is 20c, should we tell its direction?" he suddenly answered "No. Right! Thus, the temperature should be scalar" (Kritt: FO, 6/21/12). Sometimes a student would raise a question, such as, "Can we solve this problem with another method?" Rather than asking more about the student's idea or extending the question into a discussion, the teacher paused the student's curiosity and said, "We are going to move to that point soon" (Kritt: FO, 5/24/12). Therefore, in the big picture of this class, the teacher did all of the talking. When asked about the opportunity for students to construct their own questions, he responded, "There is little chance for them to ask a question or ask argumentative questions to their friends or in response to my teaching." This happened because "I think I sometimes gave them time to ask but sometimes I didn't. Overall, I think they received the information most of the time" (Kritt: RI, 8/28/12). Kritt also reflected on his questioning skills that "Most of my questions are 'how' and 'why' rather than 'what.' However, to tell you the truth, I think I am not good at questioning" (Kritt: RI, 8/28/12). He further stated, "Sometime the students still have a hard time understanding what I am asking them" (Kritt: RI, 8/28/12).

In later months, however, even though it did not occur often, sometimes Kritt would include questioning in his explanations. For example, while explaining graph interpretation he asked, "What does the graph s/t mean?" Then, the students answered that it was used to find speed since it was distance divided by time. When he asked, "From what we have learned, what happens if the speed changes?" the students then responded that it would cause acceleration (Kritt: FO, 7/12/12). Additionally, sometimes the teacher aimed to hear multi-person opinions and asked questions to facilitate this, such as "Does anyone have a different idea? Does anyone want to argue? Does anyone think this is wrong?" (Kritt: FO, 7/23/12). However, even when asking these types of questions he again rarely waited for students' responses. Even when Kritt did allow time for more than a single student to answer the same question, he did not make use of divergent answers to promote student negotiation. For instance, at one point he asked, “What do we know about distance?” and then waited a few seconds. One student answered, “It has magnitude but no direction”; another student then added, “It is a scalar,” and another said, “It uses meters as a unit” (Kritt: FO, 7/23/12). Even though all of these students provided different answers, the teacher ignored the situation and simply moved on with his lecture. In another example, he asked students, “Does the displacement have a chance to be less than distance?” One student answered that it did, while another answered that it did not. Kritt then gave the right answer without asking the students for their reasoning, reinforcing their ideas, or providing time for them to extend the discussion (Kritt: FO, 7/23/12).

Despite the lack of the teacher’s questioning, occasionally the students asked their own questions, like, “How can we get this number?” (Kritt: FO, 7/12/12) and “Why don’t we use this formula?” (Kritt: FO, 8/20/12). Even with the students initiating the questioning, however, Kritt did not use the opportunity to extend the conversation; instead, he would swiftly provide the answers. At the end of the semester, the teacher reflected on his questioning practice that, “I think I am still at the same place. Maybe my attitude has changed in that I can wait for students a little longer, which I didn’t do in the past. Also, previously when I ask them a question and they kept quiet I would wait for 30 seconds and then would give them the answer. I think I am better about this now but not good enough” (Kritt: RI, 5/24/12). When asked about why he had difficulty waiting for students’ responses, he stated, “It is because of time. While teaching, I want to complete everything on the lesson plan, which is difficult to do in this limited amount of time” (Kritt: RI, 8/28/12).

Problem Solving and Reasoning

Kritt reflected that he struggled with designing inquiry activities to promote self-directed student learning; his lessons were normally focused on facts and applying physics formulas in various complex problems rather than on developing an understanding of the fundamental physics concepts. The teacher also typically encouraged students to remember terms such as 'metric prefixes'; for example, Nano is equal to 10^9, and to practice mathematical calculations. Kritt did not change his accentuation on memorization; as noticed in one of his classes in July, he said, "I will give you some time to memorize the equations first. I may test you on this since you still can not remember it" (Kritt: FO, 7/23/12). There were times that the teacher planned to go deeper than enhancing the skill of memorization. For example, he announced at the beginning of one of his classes that "I will ask you to proof where '$tan\theta = \frac{A \sin\theta}{B + A\cos\theta}$' came from" (Kritt: FO, 6/27/12),and at another point he told the students, "I will ask you to design your own data table" (Kritt: FO, 7/23/12). But in fact, design the investigation and he did not provide time for students to explore the point he had stated in the beginning of class; instead, he demonstrated how to get this equation. This seemed to be one of Kritt's ing characteristics: he most often demonstrated and then gave a trick for main teach .calculating or solving a problem

Problem solving and exploration activities did occur a few times in Kritt's class during the semester, though he still was not successful at using them to promote self-directed learning. For example, in one of his classes in June, the teacher talked about using Vernier Caliper to measure an object. During this class, the teacher played the role of leading the investigation in that he guided a lot and asked students to follow his instruction without any reinforcement through discussion. Even though since the first interview Kritt had stated that he was concerned about his students' ability to negotiate, mentioning that, "From what I have seen so far, they are not confident in expressing their ideas or are afraid of arguing" (Kritt: RI, 5/24/12), he did not provide much opportunity for the students to practice these skills by being engaged in scientific investigation and meaningful conversation. Though some activities did have the potential to be performed through inquiry, such as 'graph interpretation' or the investigation of 'vertical linear motion,' the teacher just did not make it happen. For example, he conducted a problem solving activity using various scenarios on the topic of 'motion.' However, instead of promoting students' problem solving skills by asking them to practice by themselves, he presented the solutions on the white board and emphasized the significant points that students should remember (Kritt: FO, 7/12/12). A similar situation occurred in August. The teacher asked his students to work in groups to brainstorm ideas about graph interpretation and the analytical proof of Newton's laws of motion. He assigned the students to draw their ideas on poster papers and stick them on the wall. Kritt explained that he had conducted this activity "to try asking the students to remember the equations. I thought they couldn't remember so I wanted to change the strategy by focusing on getting them to know the source of each equation instead" (Kritt: LI, 8/9/12). However, instead of asking the students to present or compare their ideas with other groups, the teacher himself pointed out the differences and similarities of all six groups and summarized the concept on his own.

Several times after finishing a class Kritt reflected that due to time limitations, he could not do everything he had included in his lesson plan. For example, one time he said, "Today is only talk and chalk. I have no time. Right now the school has reduced the class period for the school sport day parade practicing. So, now we have just 40 minutes for each class. Also, I have to finish two units before the upcoming midterm exam. Now we are far behind schedule" (Kritt: LI, 6/21/12). He explained that because of these time constraints he had had to abandon his original plan, "Actually, I planned to ask them to find the acceleration and conclude the concept that all objects that are moving in the vertical direction would travel with this same acceleration. This would have come from their experiment but I had to shorten the process by asking them to calculate at home" (Kritt: LI, 8/28/12).

Kritt often used various modes such as symbols, pictures, or graphs to represent the phenomena along with his explanations, such as drawing head-to-tail vectors or drawing motion graphs (s-t and v-t graphs) to represent how far a car had traveled and how its speed had changed while traveling; however, even when using these modes he did all the talking. The teacher reported to the researcher that even though his class included little inquiry implementation, he expected that the students studied in more depth how to apply the concept to solve a problem while they were at home. He stated, "The application part is their job. They have to find more information too. I think this is about them developing their own thinking processes via applying their knowledge in other situations" (Kritt: RI, 8/28/12).

The teacher additionally discussed that even though he did not conduct many activities to promote students' problem solving or critical thinking skills, he realized the importance of students' understanding of physics theories. However, he mentioned that the national educational test assessed students' ability to use physics formulas to solve problems. Hence, he could not avoid devoting his class time for students to practice these skills. He stated, "Theory comes first, sure thing! But in the end, when students take a test they won't test their conceptual understanding" (Kritt: RI, 7/12/12). The teacher also stated that he had noticed that the students preferred to practice mathematical problem solving or examples of the previous years' national tests rather than learning a concept; as he stated, "I have also noticed that they are enthusiastic about solving a problem but not so active when talking about a theory" (Kritt: RI, 7/12/12).

When the students in Kritt's class were asked about their opinions on this point, they said they liked the way he taught, explaining, "He gives us all the basic knowledge that we need to use for our future study" (Kritt: SI, 8/15/12). However, the students' opinions diverged on how they preferred to learn in a physics class; one student said, "We prefer the reformed learning because at least we can think first instead of just waiting for the teacher to feed us all the information. We can improve our ideas." Another student agreed, "I also prefer the reformed learning since I have a chance to discuss my ideas with my friends. We can exchange our ideas." But a third student said,

> I like the teacher to start first. I prefer the teacher to teach and tell us first so that we get all of the information. After that when he thinks he is done transferring all the knowledge and there is nothing else that we need to know, then he can give us time to ask questions. I don't like when he just comes to the class and asks, 'Is there anything you want to say?' It isn't useful to ask us that way because we don't really have any ideas on the topic (Kritt: SI, 8/15/12).

After voicing these opinions, the students criticized their teacher's practice as relying too much on the old style, in which "He starts with telling us the information. But this is not very student-centered. However, even though mostly we just listen to him, he still gives us opportunities to ask if anyone has questions. Then, he explains" (Kritt: SI, 8/15/12). Though the students were critical of this old style, they did comment that their teacher had changed over the course of the semester since "He sometimes asks us to share ideas and talk." However, they reflected that this new learning style might not be appropriate to them because "We are just 10th grade students; we don't know much. So, we couldn't fully present or share ideas" (Kritt: SI, 8/15/12).

Learning Environment

At the beginning of the semester, Kritt shared his intention of his classroom environment that "I want students to sit in-group and to have interactions while studying such as talk in-group, present their solutions, and analyze the data, something like that" (Kritt: RI, 5/24/12). He further stated the benefit of encouraging the students to talk more, it would help teacher to evaluate "if students understand the concepts or if they are still confused or having a misconception. We can know these from their talks" (Kritt: RI, 5/24/12). However, it seemed that his intention about designing his class stated previously had not successfully implemented because he, in fact, mostly performed his teaching through a lecture-based style where teacher was a lecturer.

At the beginning of the semester, Kritt shared his intention that he wanted his classroom environment to be a place where "students sit in groups and have interactions while studying such as talking in groups, presenting their solutions, and analyzing the data, something like that" (Kritt: RI, 5/24/12). He further stated the benefit of encouraging the students to talk more; it would help the teacher to evaluate "if students understand the concepts or if they are still confused or having any misconceptions. We can know this from their discussion" (Kritt: RI, 5/24/12). However, it seemed that his intention of providing this interactive classroom environment was unsuccessfully implemented because he in fact mostly performed his teaching through a lecture-based style where the teacher was a lecturer.

Even though change was not noticeably apparent in Kritt's classroom during this study, there was a few times where he seemed to attempt it. The teacher sometimes provided opportunities for students to work in groups. For example, while measuring an object with a Vernier Caliper, he asked the students to work and discuss their activities in groups. And at one point in August he also asked his students to work in groups. However, he mentioned that he was not very satisfied with the outcome of this activity because "In some groups the members were not cooperative" (Kritt: LI, 8/9/12). When asked why he did not provide much time for students' discussion or often let them work in groups, he responded, "The students sometimes don't work well in groups since they have a short concentration span. Also we are focusing on calculation, so I didn't assign them to work in groups. Time is another issue. For these reasons I just do lecturing" (Kritt: RI, 8/28/12).

Even though Kritt arranged for the students to sit in groups while studying, there was very little dialogical interaction between the teacher and the students and among the students in this class. Sometimes the students argued to the class when they thought the teacher had made a mistake on the white board; however, there was no negotiation following up those arguments since the teacher just changed his mistake to the correct answer. Similarly, when students asked a question, he would quickly provide an answer. It is important to note that it was not only the teacher who was focused on the right answer; the students also wanted to hear it. This was evident in a class where Kritt asked, "Do I have to give you the answers?" and the students said "Yes." After hearing this he wrote the answer on the white board for students to jot down in their notebooks (Kritt: FO, 5/31/12).

Even though Kritt's views of learning did not actually appear to change, at the end of the semester he reflected on his teaching and listed his weak points regarding why he was unable to implement inquiry in his classroom. He several times mentioned issues like his lack of teaching experience, the students' abilities, and time constraints. When asked what strategy he would prefer to conduct if these concerns were removed, he answered, "I want them to work in groups using a jigsaw technique. It is like everyone is a piece of a jigsaw puzzle. Each will learn one topic and come to share with the group. If a student can learn and explain to the group, I think he/she has a good understanding of what he/she has learned" (Kritt: RI, 8/28/12). However, due to the factors previously mentioned, he could not make this happen. He further expressed about his own teaching that "I feel I didn't do what I expected to do. If the full score is 10, I would like to give myself a 7." (Kritt: RI, 8/28/12). The missing points were because "I think I didn't give them much practice on procedure and experiment. I also had less time to spend with them. At the beginning of the semester it was fine; I gave a test before we were done with each class, but later on we didn't have this due to time constraints" (Kritt: RI, 8/28/12).

Nattawee

Nattawee was another teacher who was classified into the non-shifting group as her implementation results of inquiry-based learning during the study did not change.

View of Learning

For Nattawee, learning meant gaining knowledge. She said, "In the past, the teacher was always the one who provided the information. But now, we are likely to ask students to learn by themselves" (Nattawee: RI, 5/24/12). Later in the study, she added to her ideas “When we have a question, we can come to share or learn from each other. Among students, they may share what they have learned” (Nattawee: RI, 8/28/12). More specifically, she mentioned that in order to teach physics well, a teacher needed “to assist students in learning theory by doing labs. For example, students should know where ‘sigma F = ma’ comes from. This helps them to learn better and acquire long-term memorization” (Nattawee: RI, 8/28/12). However, the teacher stated that in learning physics the students had to have basic knowledge beforehand to be able to move on to more complex topics. Thus, she thought it was important that the teacher give students the main concept first and then ask them to apply it to other problems by themselves. In her view, the teacher thus had a role as “a facilitator that guides and provides information. The teacher may explain the concept in the big picture and then ask the students to apply it. Then, the teacher and the students can conclude the idea together” (Nattawee: RI, 5/24/12).

Nattawee mentioned that the idea of promoting students to construct their own knowledge came from the Institute for the Promotion of Teaching Science and Technology (IPST, Thailand), which had emphasized encouraging students’ investigation and communication. She commented that the most important part of learning in class was to “practice and learn theory, but also to remember the main concept. If they can remember the concept, everything can move forward” (Nattawee: RI, 5/24/12). However, the teacher did not only expect her students to “remember” the concepts; in her last interview she mentioned that she now also expected them to understand the concepts. She stated, “I want them to catch the main concept of each topic. I want them to understand; for example, what does ‘linear motion’ look like? Are there any factors related to this? How do you find the velocity of a moving object?” (Nattawee: RI, 8/28/12).

The teacher further explained that there were several ways learners could gain knowledge; however, most of the time, and especially for physics, the teacher would start with lecturing or conducting an investigation if the context allowed. She commented that students, in fact, did not like to do activities or inquiry learning; instead, “They prefer the teacher to tell them what they should know” (Nattawee: RI, 7/10/12). She further added that “We have to give them information first to give them some ideas about the topic we are going to discuss” (Nattawee: RI, 8/28/12). She explained that this did not mean that students could understand the entire topic the teacher was explaining; they also needed to seek more information by themselves. Nattawee believed that “By doing this, they will gain more knowledge, a process that is called knowledge construction. Also, they may find their own trick to remember the concepts. And this is going to be their own strategy. They can construct a concept map or anything else” (Nattawee: RI, 8/28/12).

Along the same lines, the teacher further suggested that after gaining knowledge, the students would be able to negotiate their ideas with friends, which would help them to know whether these ideas were correct or reasonable. In terms of promoting negotiation in class, Nattawee explained, “After learning information, we may set up a situation. For example, we may discuss a moving car. If students don’t have any background knowledge about the first law of Newton, they don’t know the fact that an object has to remain moving according to its existing movement. Because of this, they won’t be able to negotiate” (Nattawee: RI, 8/28/12). Nattawee suggested that other than promoting students’ verbal negotiation, the teacher could also do this through writing, using it as a tool to negotiate and reflect on ideas. This was an approach she had been exposed to while attending the workshop with IPST. She explained, “Before we left the room, they asked us to write something called an ‘exist ticket.’ It asked, ‘What did you learn from this class?’ ‘What do you not understand?’ ‘Is there anything else you want to learn?’ It was a reflection or negotiation process with ourselves” (Nattawee: RI, 8/7/12).

The teacher mentioned that she intended to implement this strategy with her physics class if she had the chance because she thought it was the most appropriate strategy with which to teach physics. She commented, “For physics, if we learn about theory, doing an experiment is good because it shows students a real example. It is a way to verify a theory. They will understand the concept and a way of thinking. But if it is about problem solving, we should ask them to practice" (Nattawee: RI, 5/24/12). She further mentioned that the teacher might demonstrate one or two examples before asking the students to practice by themselves. However, she thought the teacher should walk around to check whether students understood the problems or had questions while studying.

Overall, then, Nattawee expressed her opinion that it was possible to learn physics by inquiry. Even though her voice conveyed hesitation, she presented the positive attitude that, "Inquiry is hunting knowledge. Physics is also about hunting knowledge. Even though people read the same books, each of them will come away with a different meaning. So, when we discuss after reading, it is also normal that one person thinks one way while another thinks another way. If we negotiate, we should be able to find the correct common idea. Therefore, it may be possible to learn physics by inquiry" (Nattawee: RI, 8/7/12). She then connected this idea to her own class, pointing out that each student also held different ideas, and that students could arrive at the same answer using different formulas and solutions. Thus, she believed, negotiation could definitely occur in a science classroom.

Teaching Practice

Figure 4-10 shows that Nattawee's performance on the three observed criteria was flat in that her scores were low and did not improve over the course of the study.

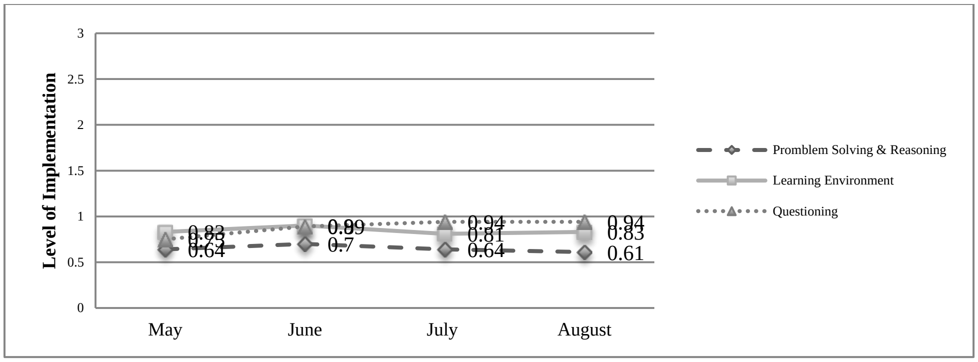

Figure 4-10 Nattawee's Level of Implementation of the Observed Criteria

Questioning

As shown in figure 4-11, even though this teacher did not incorporate very much questioning into her classes, the number of questions she asked did increase every month over the course of the study. Of these, medium-level questions occurred most often in every month. However, evidence from the researcher's field notes suggests that when asking a question, Nattawee expected her students to provide the correct answer, which sometimes led only to simple yes/no answers or short responses.

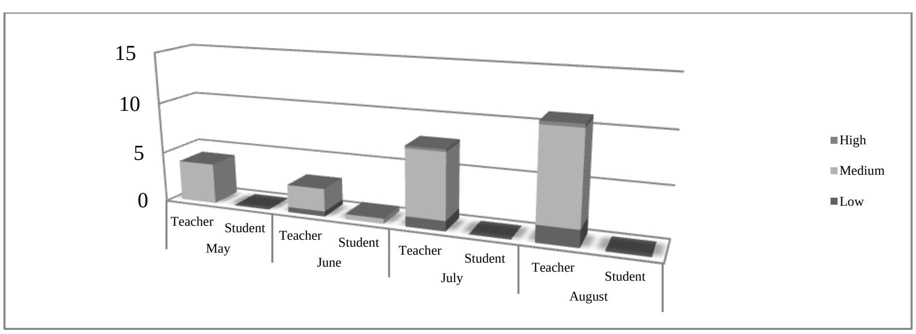

Figure 4-11 The Frequency of Questioning in Nattawee's Class

When asked to comment on the role of questioning in her class, Nattawee explained, “When we solve a problem, I am not directly telling them the answer but instead am asking them what they should do. For example, in the topic of movement, I asked the students what is this question asking, what does it tell you. I asked them; I didn’t tell them” (Nattawee: RI, 5/24/12). There were many times that Nattawee utilized a simple question or a direct knowledge question that relied on students’ memorization, such as “What is the national unit that we use the same all around the world?” or “How many units do we have in the SI?” (Nattawee: FO, 5/24/12). She identified that she did not normally use high-level questions, but sometimes she used them to assess her students’ conceptual understanding; for example, “What is the difference between using a Vernier Caliper and a micrometer?” (Nattawee: FO, 5/31/12). She would also occasionally use high-level questions to promote critical thinking, such as “There is one truck and one car. If they are moving with the same velocity, which one needs a longer distance in order to stop?” (Nattawee: FO, 8/14/12) or “Between the velocity at the point that the object touches the ground and the highest point it can reach, which one is more?” (Nattawee: FO, 7/26/12).

Despite Nattawee’s occasional attempts to ask such questions, however, the usual result was that students would provide only simple answers without clarification, and the teacher did not encourage further discussion. For example, in answer to Nattawee’s questions about velocity, the students simply answered, “At the point it touches the ground” without explanation. Additionally, many times the students would not respond to the teacher’s questions at all. She commented, “I normally use questioning but the students seldom answer me” (Nattawee: LI, 7/26/12). She guessed that this might be because some of them really did not know the answers; some knew the answers but did not know how to explain them; and some might just be too lazy to respond.

When asked about providing the students with opportunities to construct their own questions, the teacher stated that she had a few students who were always active in her class and they normally asked her many questions. She explained, "Like today, they asked why '$N = mg\ sin\theta$'. They had a question about why. I explained by guiding them to think and figure out the answer by themselves. I guided but didn't give them a direct answer" (Nattawee: RI, 8/28/12). Her statement was congruent with the students' recollection of this event; they said their teacher would not give them a direct answer, but instead that "She guided the procedure and asked us to think by ourselves" (Nattawee: SI, 8/7/12). The students commented that this strategy was useful since it was challenging and they could think before receiving the right answer.

However, the entire class did not actively respond to Nattawee's questions. She mentioned that many students still asked her to provide a way to solve a problem, explaining, "They are not asking for a procedure. Instead, they are asking me 'What formula should I use? Is my answer correct?'" (Nattawee: RI, 8/28/12). The teacher stated that she tried not to give these students the answer immediately but instead tried to challenge them in return. For instance, she might say to them, "Explain to me the situation of this question; what do you think? Are there any factors you think are related? How many possible formulas can we use?" (Nattawee: RI, 8/28/12). Nattawee explained her strategy for doing this; "I will ask them to draw a picture first; then we can talk about what formula we should use. If I give them the answer right away, that's done! They won't think" (Nattawee: RI, 8/7/12). Though initially the teacher had planned to use questions that promoted students to think, it seemed that these 'open-ended' questions sometimes did not work well in her class because of her students' short responses. Thus, instead she had to utilize short answer questions and had "to provide information and sometimes quickly pause for them to fill in the answer" (Nattawee: RI, 8/7/12). In other cases, the teacher reflected that, "I needed to start with a broader question and narrow it down since they couldn't answer it at first" (Nattawee: RI, 8/28/12).

Nattawee sometimes used questioning to assess students' prior knowledge, such as their understanding of the first law of motion. For instance, she asked the students, "What is an example of Newton's first law in your daily life that you can come up with now? (Nattawee: FO, 8/14/12). She clarified that she asked this question because "I really want them to use their imaginations and think about Newton's first law, F = 0; how can an object maintain a steady motion? How does this happen? And then I want them to be able to connect this understanding to their real experience. So, I asked what situations they can come up with" (Nattawee: LI, 8/14/12).

This class did not incorporate many exploratory activities; thus, only a small number of investigation questions appeared. Most of the questions were instead about problem solving and many appeared in written form as part of handouts prepared by the teacher. When asked to examine her teaching over the course of the semester, she expressed that she had "tried to use more questioning. For example, when learning a concept, I will ask them to think more. Like with Newton's law, I would ask students which situation could be explained by Newton's law of motion" (Nattawee: RI, 8/28/12).

Problem Solving and Reasoning

Nattawee taught advanced physics, which actually built on from the foundation of physics course taught by another teacher. Thus, she clarified to the researcher that in her class students practiced more complicated problem examples. Even though it did not occur often, the teacher thus sometimes conducted activities that were intended to promote problem solving and critical thinking skills. For example, while talking about measuring an object using a Vernier Caliper and micrometer, the teacher suggested that her students observe that these instruments were appropriate to measuring tiny objects such as coins or papers. She also provided opportunities for students to discover knowledge by themselves. Nattawee mentioned that she sometimes let students start their learning with curiosity before the formal presentation. An illustration of this was when one student came to her and asked why he got different numbers when using the Vernier Caliper and micrometer to measure the same object. Then he asked which instrument he should use. The teacher expressed that she had hoped students would ask these kinds of questions. She said, "The Vernier Caliper and micrometer have different magnifying scales. The micrometer is more accurate than the Vernier Caliper. So, the numbers the students got would be different, which is correct. I want them to reach the point where each instrument works well for different purposes and I want them to be able to pick which instrument they should use while measuring a very tiny object." The teacher also aimed for her students to learn that not every tiny object could be measured by a Vernier Caliper. With this in mind, she then assigned the students to measure their own hair using this instrument until they found this fact out and said, "Teacher, this cannot be measured by a micrometer or a Vernier Caliper" (Nattawee: LI, 5/31/12).

After they were done exploring, the teacher asked the students to design their own data table. She explained, "If I design a table for them, they won't think through the ideas. So, I asked them to do this in order to try to get them to practice thinking" (Nattawee: LI, 5/31/12). Nattawee additionally stated that during this activity she had tried to implement the ideas she had learned from the ABI workshop. She said, "I think the students should be able to think by themselves about how to record the results of their investigations" (Nattawee: LI, 5/31/12).

The teacher often encouraged her students to use diverse modes of representation such as drawing pictures or symbols while solving a problem to pull out the information from the questions; for instance, she would encourage them to draw the direction of a tiny rock falling down from a cliff. She would tell the class, "Try to draw a picture to represent what the question is asking you" (Nattawee: FO, 7/26/12). She additionally emphasized that students be able to interpret graphs since this is part of presenting results and data in physics. Nattawee clarified that the students should be able to explain the relationships among any observed factors, mentioning, "Mostly, the data in physics are explained by graphs. For example, we can explain speed from the relationship of distance and time. Thus, it is necessary that students have background knowledge about graphs"

(Nattawee: LI, 6/5/12). The teacher stated that she also wanted her students to practice their communication skills, commenting that the weak point of Thai students was that "They can't write or explain their reasoning logically and systematically. I want them to be able to write or communicate their ideas in a way that is understandable to others" (Nattawee: RI, 8/28/12).

Even though teacher demonstration and lecturing seemed to be the defining characteristics of this class, Nattawee sometimes asked her students to exhibit their problem solutions in front of the class. She explained, "I want to know if they are able to solve the problems. Sometimes they just copy my answers. So I want to know whether or not they can do it by themselves. This is my strategy to check if the students understand what I have been teaching and how well my teaching is working" (Nattawee: LI, 5/24/12). The teacher expressed her belief that the more students practice the more they will do well on tests. Thus, she decided to include diverse problems for students to practice on in class. She emphasized, "It will be beneficial for them to have a chance to prepare beforehand for the test" (Nattawee: LI, 6/28/12).

Nattawee commented that her students had some previous knowledge of the concepts she was teaching from their foundation physics course. Therefore, she did not have to mention these much again and hence had decided to instead spend her class time focusing on complex questions on which her students could practice. A demonstration of this occurred in one class where the teacher assumed that her students already knew about the concept of 'the ticker tape timer' topic from their other course. Hence, she moved to the calculation part of this topic. This method of teaching seemed to satisfy the students. They reflected that "She is strong in content knowledge" and her class was "challenging both in content knowledge and problem solving activities" (Nattawee: SI, 8/7/12). They further noted that this teaching technique had not changed over the course of the semester. What Nattawee had been doing was to "introduce a formula; then she will explain where it came from. She provides information and she asks us to memorize the concepts" (Nattawee: SI, 8/7/12).

Memorization was the central skill that Nattawee encouraged her students to practice. She seemed very concerned with finding the right answers and always gave her students the correct solution to every problem before the class was dismissed. She mentioned, "The reason that I still have to give an answer at the end of class is because there are some students who cannot follow me. Some of them just draw a picture and have no idea what to do next. So, I have to elucidate the procedure for them" (Nattawee: LI, 7/26/12). Nattawee mentioned that she was concerned about her students' ability to present their problem solving procedures, saying, "I am now afraid that the students cannot do the midterm exam and could not explain their procedures. The problem with learning physics is that students cannot perform their explanations step by step. It seems that they don't know how to do the problems and where to start" (Nattawee: LI, 7/3/12). Nattawee's concerns about her students' competency were evident, and her students affirmed this, commenting that, "She cares about students. When we don't understand, we can ask any questions and she will come explain to us individually" (Nattawee: SI, 8/7/12).

The teacher's concern for student learning was strongly tied to her intention to prepare students to perform competently in school exams and the national education test. Thus, the activities in this class were normally designed to promote skillful problem solving, which was typically related to mathematical calculation. Nattawee mentioned several times that, "I want them to be able to analyze and solve a problem because they will face this kind of problem again when taking a test" (Nattawee: LI, 8/7/12). The teacher also commented that the reason Thai education could not successfully implement reformed learning as suggested by IPST was because "The national educational test is too difficult. Students like to do problem solving because their goal is taking the national test to get into the university. Even though argument-based learning helps students to understand the concepts clearer it is not the best method to use" (Nattawee: RI, 8/28/12).

Nattawee recognized that even though physics was very similar to mathematics in its focus on problem solving, which requires mathematical skills, learning the other components of the discipline could be aided by a reformed learning approach. She emphasized that "When we learn theory, we can use argument-based learning to help students gain more understanding. But when taking theory into problem solving, I think argument-based learning can work well only with some students that actively talk" (Nattawee: RI, 8/28/12). Nattawee further pointed out that if the Thai educational system continued to evaluate student achievement with grades or an exam that focused on memorization or mathematical skill rather than on critical thinking or problem solving, "We still have to teach by the traditional method and students have to remember all concepts and formulas to be able to take the test. As we all know, the national exam still emphasizes content. It doesn't really focus on concepts" (Nattawee: RI, 8/28/12). Accordingly, the core of teaching physics for Nattawee was "The more students practice, the more they can solve the problems. It is the nature of physics that learners need to explain the phenomena and solve the problems. Under this purpose, we have to teach them to be clear on theory, to remember all concepts, and then to be able to use the concepts to solve any problem" (Nattawee: RI, 8/28/12).

At the end of the semester the teacher reflected that her teaching style was "not so student-centered. I give information to students first. This does not let them learn by themselves for the entire process" (Nattawee: RI, 8/28/12). This happened because she had to cover all of the required topics on time, which was very difficult and was a big barrier; she explained,

> Actually we have to do experimenting but sometimes we have time restraints, so we have to do a dry laboratory instead. I actually try to talk about theory to help students understand the concepts first. Then, I push them to bring this theory to bear on solving the problem by themselves. That's the main thing that I have to do (Nattawee: RI, 5/24/12).

At the end of the semester, Nattawee stated that she had tried to minimize her role in class but still needed to lead students through how to work through a problem. She reported, "I try not to give them the answers but instead ask them to find the answers by themselves. However, I have to start by demonstrating one example so they will know what to do while facing this kind of problem. It is like I primarily give them the direction they need to follow" (Nattawee: RI, 8/28/12). By this time she had also added a technique to encourage students to construct their own knowledge; she explained,

> After the lesson is done, I have tried to encourage them to study at home and repeat the lesson. I ask them to make notes that will help them record their own understanding. When jotting down their own notes, students understand what the notes mean and where the ideas come from and they can make connections between all of their ideas (Nattawee: RI, 8/28/12).

Learning Environment

Most of the time, Nattawee's activities aimed for her students to work individually since she elucidated that she was afraid that the students would copy their friends' answers. She preferred her students to come up with the answers by themselves; consequently, she only conducted investigations in her class a few times. In general, the teacher lectured on the concepts and then let the students practice on the questions she provided in class materials. At the end of each class the teacher gave the answers on the white board or if time allowed she sometimes asked the students to demonstrate their solutions.

Nattawee had attended the Pedagogical Content Knowledge (PCK) workshop, where she learned several classroom teaching techniques such as jigsaw, gallery walk, etc. While she acknowledged that these techniques "are interesting and good for promoting student learning I still haven't tried them yet" (Nattawee: LI, 7/3/12). The teacher assumed it might be difficult to use a variety of activities or strategies in her classroom since she had diverse students with different levels of learning abilities. She said, "Sometimes, I teach the whole class at the same time. There are some students that are quick to understand while still many of them are slow; I will have to let them [the slow students] go because each student has a different learning ability" (Nattawee: RI, 8/7/12). Nattawee commented that most of her students liked to learn when she brought mathematical problems into class because they had already learned theory from another course. Hence, they expected to have a chance to practice with more complex mathematical problems in her class. Nattawee further mentioned that the school expected her class to help students cram for the national examination.

The teacher sometimes asked students to demonstrate their solutions in front of the class; however, normally the students just wrote down their solutions without any verbal explanation. In addition, those who were called upon to present their answers were normally from the same small group of students. Nattawee's students commented that this was because sometimes the teacher only paid attention to the group that learned fast. They complained, "She may not know that my group is slow and we sometimes do not get the points. So, I want her to spend more time with my group" (Nattawee: SI, 8/7/12). However, Nattawee's view of the situation was very different. She told the researcher, "Mainly, I want them to practice solving problems. I like my students to work on their own, but they can ask me any questions they want. I actually have to spend more time on the low ability students. Rather than explaining one time, sometimes I have to repeat the basic information to them" (Nattawee: RI, 8/7/12).

Nattawee mentioned that during the problem solving activities, sometimes the students discussed the solutions and this made her class look chaotic. She said that other teachers sometimes did not understand that this was why her class was messy and noisy since they thought a good class must be quiet. Yet her own opinion differed; she commented, “For me, I want students to be a part of the lesson in that they have opportunities to think and talk. Because if they just sit and copy my answers, we can easily finish our class but students will learn nothing” (Nattawee: RI, 8/7/12).

The teacher’s relaxed attitude about her classroom environment was also reflected in her decision to let students choose who they wanted to sit with. She noticed that in her classroom this meant that “the boys like to sit in front of the class because they like calculation and like to ask questions” (Nattawee: RI, 5/24/12). Even though she did not often conduct group work, Nattawee said that by arranging students to sit in small groups, they would have a chance to discuss problems. She explained, “They discuss. ‘I cannot do this. What is your idea?’ They help each other. I try to ask if there is anyone who doesn’t understand; then I walk to that group” (Nattawee: RI, 5/24/12).

Despite Nattawee’s good intentions to provide a classroom environment that supported student work, however, she most often did not provide enough waiting time for the students to think or respond to her questions. Therefore, her questions were mostly answered by the teacher herself. For example, she asked the students, “Now that we know ‘sin’ and ‘cos,’ how can we find tan?” (Nattawee: FO, 6/12/12). Without offering any time for the students to reflect, the teacher suddenly answered “$\tan = \frac{Sine}{cos}$” (Nattawee: FO, 6/12/12). Similarly, when the students asked her a question about this formula, Nattawee did not challenge them back with a probing question as she had planned to do. This action was consistent from the beginning until the end of the semester.

When asked about the dialogical interaction in her class, Nattawee mentioned that it was not explicit since she did not often establish investigative activities. Therefore, normally the teacher communicated with students while she walked around the classroom. She mentioned several times that she “mostly focused on individual working” (Nattawee: RI, 7/10/12) because she was afraid that the students would not think on their own but would instead just copy their friends’ answers. However, she did not prohibit but rather really welcomed when the students wanted to discuss ideas or problems in groups.

She explained, “I want them to start thinking by themselves first. If they can’t understand a problem it is okay for them to ask friends. Naturally, people have to think by themselves first; then, if they encounter a problem they will discuss it with others” (Nattawee: RI, 8/7/12).

However, Nattawee mentioned that her students were very poor at communicating their ideas to others. When she asked the students who finished the questions early to explain their solutions to their friends, she reported, “They came back and told me that teaching friends is difficult. They said it is easier to work individually. It is not easy explaining the solutions to friends because they don’t know how to explain” (Nattawee: LI, 8/7/12). The teacher further commented that the nature of Thai students was a hurdle to employing argument-based inquiry in the classroom. She said, “Students are afraid of talking in public. They are afraid of discussing. They are afraid of providing a wrong answer. They don’t want to be ridiculous in front of their friends. Additionally, they may not actually understand the concepts they are learning; that’s why they cannot explain them” (Nattawee: LI, 8/7/12).

Nattawee mentioned that it was perhaps because of these reasons that her students preferred to work alone. There was just one group of students that appeared to use negotiation during learning; the other groups were too shy. The students in those groups liked to ask a question or discuss things with the teacher individually. However, she noticed that the students always talked; also, “They discuss and teach each other like peer-to-peer teaching” (Nattawee: RI, 8/28/12). Even when students appeared to negotiate with one another, the teacher sometimes was not sure whether the action that was occurring in her class was inquiry learning, and she also felt that this negotiation sometimes occurred by chance. She said, “In order to choose a proper formula, they have to think and analyze carefully. ‘Do we call this inquiry?’ They came up with a different approach but got the same answer. They sometimes ask each other, ‘Why do we use this formula?’ ‘Why is v negative? Why wasn’t it positive?’ This is negotiation, I think”

(Nattawee: RI, 8/7/12). The teacher then decided that even though an explicit inquiry did not emerge here, this was a part of the inquiry learning she performed in her class. She also acknowledged the difficulty of including this type of learning in a class like physics, which was different from other subjects such as social science in that “Those more explicitly include argumentation. Students can do presentations or questioning in those classes, but in physics we couldn’t do many presentations or include much argumentation except when we did experiments and each group got different results” (Nattawee: RI, 8/7/12). Though these activities could result in inquiry learning, Nattawee noted that it was impossible to include experiments in every class due to time limitations.

In later months the teacher reflected that she thought she talked too much in the class. She declared, “I think I should let them play more. I also think that I talk too fast but I think the students are familiar with my style” (Nattawee: RI, 7/10/12). Once, the teacher informed the researcher before her class began that today she planned to ask students to discuss in groups. However, she did not end up doing what she had intended. After class she explained that she hadn’t done this activity because “the students did not understand the concept and they really wanted my explanation. Also, we will have a test this Thursday. So, we have to speed up the lesson” (Nattawee: RI, 7/10/12). The teacher further mentioned that time limitations were a big barrier for her teaching. She said, “If I had the time, I wouldn’t teach this way. I would teach theory first and would ask them to think in different situations and ask them to practice on various problems. For instance, I might provide four examples and then ask them to practice by themselves. But I don’t have time” (Nattawee: RI, 8/28/12).

Other than time constraints, the students’ learning goals, and colleague pressure were the factors that influenced Nattawee’s teaching. She mentioned, “Many teachers expect students to be able to solve very difficult problems. Actually, it is good enough if they can just understand a concept and use it to solve a problem” (Nattawee: RI, 7/10/12). However, she reflected that she did not follow this principle but rather tried “to teach both problem and theory. They have to be sure about the concepts" (Nattawee: RI, 7/10/12). Nattawee also commented that even though IPST encouraged teaching physics by inquiry, several factors, including time limitations and the amount of required material, limited the feasibility of this method. It seemed impossible that teachers would be able to finish every required topic on time.

Nattawee suggested that if the national educational test could be changed to assess students' comprehension, teachers could then also change to teaching by focusing on procedure and could implement a teaching approach that promoted students' cognitive thinking skills, such as argument-based inquiry. Thus, they could change to including more experimentation and discussion of various problem scenarios. Even though she agreed with the idea of teaching science by inquiry to promote student knowledge production, Nattawee believed that until these circumstances changed teachers would need to continue to teach didactically. She explained, "I think the national assessment test impacts students a lot. Students learn by experimenting but they will eventually face a very difficult test. The situation is controversial" (Nattawee: RI, 8/7/12). It was evident that Nattawee's teaching approach and her students' learning goals were matched since the students reflected that they were satisfied with her teaching. They said, "I like her teaching because she provides time for us to practice. I like to know formulas and theories because it will be worth it when we take the test" (Nattawee: SI, 8/7/12).

Conclusion across Cases

Based on the teachers' accomplishments in practice during the implementation phase of the ABI approach, as measured by RTOP scores, this study divided the participants into two groups: (1) the shifting group, consisting of three teachers who were beginning to shift their teaching practices (Ausanee, Kamonwan, and Sutisa); and (2) the non-shifting group, including the two teachers (Kritt and Nattawee) whose practices were not changing. Throughout the semester of investigation, the researcher found that the three teachers in the shifting group began to shift both their views of learning and their teaching practices. However, each teacher started to change these skills at a different point.

As reflected in their interviews, the participants in this study improved their understanding of the ABI approach throughout the semester. Largely, the teachers thought that there were many strategies that they could employ to implement inquiry learning into their classrooms. Both groups of teachers realized the importance of changing the emphasis from a cookbook dependency to a greater focus on students' involvement in class activities as well as of enhancing students' voices as necessary components of an argumentative classroom where students were the center of learning (Ballone Duran, McArthur, & Van Hook, 2004; Simon et al., 2006; Fetters, Czerniak, Fish, & Shawberry, 2002).

Although the teachers in both groups valued the significance of a student-directed model of learning, their perspectives of cognitive-based learning varied from teacher to teacher, and these perspectives impacted their practices. To clarify, the teachers in the shifting group believed that teachers have authority to freely design their own inquiry lessons, and that students also have their own power to perform learning and voice their thoughts in class. Therefore, the teachers in the shifting group used different avenues to conduct their inquiry classrooms. For example, Ausanee focused on using different types of questions in her class, as she believed that questioning was a tool to engage and promote student learning. Sutisa created her class's activities based around group work because she thought cooperative learning was the best method of supporting students' knowledge construction. On the other hand, the teachers in the non-shifting group sometimes interpreted inquiry to mean simply the use of hands-on activities involving no student interaction. Thus, they often maintained their lecture-based classrooms rather than emphasizing the growth of students' individual mathematical problem solving skills.

In the big picture of this study, the teaching performance of the shifting group grew continuously throughout the observation period, while the non-shifting group's performance remained unchanged. The particular aspects of each group's change are explained in detail below.

The Shifting Group

Throughout the semester of observation, the teachers in this group commonly began to change both their beliefs and practices, although practice was the area they first attempted to shift. The teachers initially expressed a moderate understanding of student-centered learning. They explained the techniques they had used to conduct inquiry lessons, including investigation, discussion, and group work. The three teachers all agreed that learners could construct their own knowledge. However, they commented that teachers must be the originators of the basic information and explain theories to students before the students could construct their own knowledge.

At the end of the semester, the teachers' views of learning had changed, as evidenced by the fact that they started to mention the importance of including student participation in their class activities. However, they continued to stress that students must obtain information before advancing their process of knowledge construction, suggesting that this information might come from either the teacher or from students seeking knowledge from other sources. The teachers maintained this idea because they believed that their students had no background knowledge of new topics; thus, they needed basic information before they could go on to learn for themselves.

In terms of the shift in teaching practices, each individual teacher presented her own means of establishing an argument-based classroom practice. The evidence from the researcher's field notes and teachers' interviews consistently showed that at the beginning of the semester the three teachers in the shifting group performed their teaching by means of lecturing. Furthermore, their role in the classroom was that of a knowledge dispenser in that the teachers were the key people driving class activities. However, over the course of the observation period the three teachers' views of learning gradually moved toward the inquiry perspective, and they began to shift toward more communicative interactions between themselves and students and between students and their peers, which occurred more often during the end of the semester. There appeared to be a parallel shift in the views of learning and teaching practices of these teachers.

As this study focused on three critical components of the ABI approach involving questioning, problem solving and reasoning, and the establishment of a learning environment, these criteria were used to examine the change in teachers' practices. As previously mentioned, when considered as individual cases, the study found that the starting point of each teacher's change in practice was different; these are explained as follows.

Ausanee

Ausanee's practice focused greatly on questioning, and this was constantly the skill she relied on to enhance student-centered learning. In her class she used various types of questions, many of which became more open-ended as time went on. In addition, Ausanee attempted to employ higher-level questions for different purposes, such as using questioning to enhance students' conceptual understanding, promote negotiation and multi-person conversations, and develop students' critical thinking and problem solving skills. Although many times the students were silent or their responses were not very effective, and her wait time for allowing students to think about and reflect on her questions was still inadequate, Ausanee's questioning skills developed noticeably throughout the semester.

Ausanee reflected that she had moved from asking '*simple questions*' that just looked for a correct answer to asking *'probing questions'* that encouraged students to elaborate their ideas. By the end of the semester the teacher asked more reasoning questions that aimed for students to explain their procedures because she thought this would help them to think critically and logically. In addition to her questioning development, the teacher also improved her teaching skills related to problem solving and establishing a learning environment. In sum, her skills on the three observed criteria improved simultaneously and her role in the classroom began to shift toward the ABI learning approach.

Kamonwan

Kamonwan not only continuously developed her understanding of inquiry learning, she attempted to improve her teaching by conducting a variety of activities in different settings to engage students and to promote classroom interactions. Among the five teachers in this study, Kamonwan was the one who achieved the highest scores during the implementation phase. She endeavored to improve all three teaching skills at the same time.

Initially, Kamonwan's class focused on mathematical physics. She combined the ABI approach with the lesson plans she already used by providing some spaces for students to argue about their problem solutions or to discuss and explain the most appropriate formula for solving a problem. Normally, the discussions in her class occurred mainly in small group settings. Even though whole class discussions were also created for students to present their ideas, many times the teacher was still the one who described the main idea for the class, and she did not reinforce multi-person conversations. Thus, in this setting, students typically answered the teacher's questions or just shouted out their ideas. Meaningful discussions, negotiations, or long conversations rarely occurred among students or between the teacher and students during a whole class setting. However, Kamonwan worked to continuously improve her skills and to try to compatibly unify all observed criteria, such as by using questioning during problem solving activities to reinforce students' discussion. Her improvement continued throughout the semester and her classroom was constantly developing toward an inquiry-based environment in which she became a mentor who supported self-directed learners.

Sutisa

Sutisa began her practice with the building of a learning environment. From the first interview, she focused on the ideas of collaborative learning and happiness in learning as the most important points she wanted to emphasize to her class. To be congruent with her beliefs, she decided to create a non-threatening learning environment where students could be relaxed, free to talk and enjoy learning. She believed that students would not learn well if they were in an atmosphere filled with tension. Thus, she could accept some off-track behaviors, such as chatting or ignoring class participation, because she understood that this was the nature of students. Sutisa also focused on collaborative learning, a focus that directly came from her belief that students would learn better if they could share knowledge or explain their thoughts to their friends. Thus, in most of her classes she assigned students to work in small groups or paired learning where they had opportunities to communicate their ideas and interact with one another.

Despite her focus on creating a collaborative learning environment, Sutisa also worked to develop her questioning and problem solving skills, attempting to link these criteria together. At the end of the semester the teacher seemed to struggle to maintain her implementation of the ABI approach due to her concerns about time constraints and preparing students for the school's final exam. However, she commented that she had not given up on the process and still wanted to continue improving her teaching practices.

Like Sutisa, every teacher in the shifting group retained a positive attitude about the ABI approach and was willing to work to improve their implementation process. All of the teachers developed their skills on questioning, problem solving and reasoning, and establishing a learning environment. Even though they began changing their practices at different points, all three teachers came to realize the importance of questioning in class and how it impacted students' engagement. They were increasingly able to appreciate that questioning not only works to develop cognitive functions by scaffolding student scientific thinking, but also helps to develop social interactions that establish good associations among students (Oliveira, 2010). Thus, their progressive improvement on questioning was a good indicator of the teachers' implementation of the ABI approach.

As their views of learning began to align with the inquiry approach, the teachers started asking questions geared to a high cognitive level. Meanwhile, they also created activities more centered on critical thinking by requesting students to explain their reasoning and procedures rather than simply giving the right answers. In addition, the teachers tended to have more patience, providing longer wait times for students to think, work, discuss, and respond to their questions; this longer wait time then impacted student involvement and contributions to learning (Baker & Piburn, 1997). Besides their improvement in the three observed criteria, the teachers also lowered their demands in class by offering students a sense of authority to perform their own learning. The researcher observed that students became better able to discuss, come up with their own questions, and think of solutions to the problems. This changing learning environment therefore seemed to be effective in boosting the shift toward student-centered classrooms.

The Non-Shifting Group

Compared to the previous group, the two teachers in the non-shifting group had less developed ideas about the inquiry learning approach and seemed to struggle more with their concerns. Although they could describe their knowledge about the effectiveness of inquiry learning, they also shared their hesitations about using this approach. For example, the teachers were concerned about the appropriateness of the approach for Thai students, as well as about the students' ability to negotiate and perform their own learning. Though their beliefs about reformed learning differed, neither of the teachers in this group was against the approach.

Kritt

Kritt began the study with his understanding of inquiry learning. He could explain the essence of inquiry, although not in great detail. His overall attitude was neutral; he was neither against nor excited about the approach. However, he sometimes mentioned his confusion about how to transform the theory into practice. He described a loss of direction for implementing the approach and requested a good model of each physics topic that he could follow, explaining that good examples from experts would help him and other teachers to teach the right way. Due to these comments, the researcher realized that even though the teacher could explain the effectiveness of inquiry, he did not have a real understanding of the essence of the new approach; additionally, his knowledge of the approach did not mean that Kritt would accept it and use it in practice. He might have agreed with ABI's effectiveness once it had been modeled by an expert, but even so might still have struggled to implement the approach in his classroom. Thus, this may lead him to decide to abandon his attempt to implement the ABI approach.

Nattawee

Nattawee's view of learning was sometimes conflicted and it seemed that this view mixed teacher-centered and learner-centered orientations. The teacher sometimes mentioned her beliefs about the appropriateness of inquiry to science learning and she was able to describe the process of this approach. In the meantime, she also stated that a teacher-centered instructional approach was more applicable in the classroom.

At the end of the observation period both Nattawee and Kritt began to share their thoughts about the importance of involving student participation in the learning process as a means of promoting knowledge construction. This revealed that these two teachers had started to think about the idea of fostering active learners in a classroom. However, their actions were still centered on delivering content.

In terms of teaching practices, *'teachers as lecturers and demonstrators'* was the common characteristic of the teachers in this group; they focused on factual knowledge and trained students to become familiar with strategies to solve problems. Kritt used demonstration as his major strategy in class. Although Nattawee conducted problem-solving activities and more often provided time for her students to solve problems on their own, most of her activities involved students solving mathematical physics problems and they were assigned to work individually. Thus, it was difficult to observe student-student interactions, class discussions, and collaborative learning in her class. Another common practice of both teachers was that their teaching was led by the school's learning goals; the teachers commented that it was their main responsibility to train and assist students to do their best on the school tests as well as the national examination.

To summarize, the teachers in the non-shifting group continued to use lecture-based instruction and focused on individual learning. Their demonstration and lecturing, which simply requested that students memorize equations and physics formulas and follow the teachers' instructions, were characteristics of the classroom environments of this group. The teachers did not challenge students' thinking with different questions or thought-provoking activities; rather, they focused on facts and problem-solving strategies that highlighted mathematical calculation and numbers. The teachers also did not provide time for students to develop their cognitive knowledge construction through inquiry-based activities or group discussions. This style of teaching did not improve students' interest in learning physics since they did not appreciate the value of the concepts; instead, both teachers and students simply wanted to meet the curriculum requirements. Thus, the practices of these two teachers did not appear to align with reformed learning. The teachers strictly adhered to their lesson plans and the curriculum and their implementation of the ABI approach was shielded by their internal and external concerns.

Summary

This chapter expressed each individual as well as the trend among the five teachers' views of learning, and their pedagogical practices by focusing on questioning, problem solving and reasoning, and establishment of a supportive learning environment. Furthermore, the concerns and difficulties that the teachers experienced throughout the semester have been revealed. The next chapter will be presented the discussion of the findings based on the two research questions, the assertions of the study, limitations, and implications for professional development and future research.

CHAPTER 5

DISCUSSION AND IMPLICATIONS

This study examined the shifts in teachers' views of learning and pedagogical practices throughout the implementation phase of the argument-based inquiry (ABI) approach. Following from the results presented in Chapter 4, the purpose of this chapter is to discuss the findings and present the assertions that emerged in this study. Finally, the study's limitations are examined and implications for professional development and future research are discussed.

Discussion of Findings

Individual teachers hold different beliefs (Bryan, 2003), and these beliefs may shift through the reformed learning process (Hancock & Gallard, 2004). However, individual belief systems are complex. Therefore, there is not only one way to explain the relationship between teachers' beliefs and their practices. Several studies have claimed that teachers' beliefs are reflected in their classroom practices (Borko & Putman, 1995; van Driel, Beijaard, & Verloop, 2001; Yerrick et al., 1997), while other literature has shown that sometimes teachers' practices also shape their beliefs (Simmons et al., 1999; Anderson, 2002). Thus, one definitive model cannot be applied to every teacher and every situation.

As explained in Chapter 1, this study was conducted in a Thai educational context where both teachers and students have been familiar with a lecture-based approach for a long time. Therefore, the introduction of the ABI approach, which is based in cognitive learning theory and which suggests that learners should play an active role in constructing their own knowledge through investigation and negotiation, is a new learning strategy for all participants. To investigate how the ABI approach is effective and appropriate in Thailand, it is crucial to begin with exploring teachers' views of learning and their teaching practices. This study therefore aimed to: examine teachers' shifting focus on the two spaces (view of learning and practice); comprehend their change; and determine the relationship among the observed skills involving questioning, problem-solving and reasoning, and the establishment of a supportive learning environment.

According to the results, the researcher found the trend of the change among the five teachers of this study, as described below.

The Change among the Five Teachers

The two groups of teachers in this study exhibited different attitudes toward and willingness to experience the reformed learning approach. Hence, how they reacted to the implementation phase and the change in their beliefs and practices were different.

After having been introduced to the new theoretical learning concept, the teachers in the shifting group tried to develop their understanding and then exposed their willingness to experience the ABI approach. The teachers in this group actually started the process with a positive attitude toward student-directed learning. This may have been a factor in driving the teachers to transform their theoretical ideas into practice in the classroom environment (Keys & Bryan, 2001; Bray-Clark & Bates, 2003; Guskey, 1988; Loughran, 1994; Ghaith & Yaghi, 1997; Miskel, McDonald, & Bloom, 1983). Therefore, in their classes these teachers used a variety of questions, created inquiry activities, and expanded class time for students to work in groups. Throughout the semester, the teachers continuously attempted to improve their pedagogical practices.

All three teachers achieved the same pattern of change in that they initially started implementing the new approach after being challenged in their views of learning during the ABI workshop. The teachers then revisited their beliefs as the next step. Although these three teachers began their shift at different starting points, they held in common the fact that they changed their practices first. For example, Ausanee began with questioning, Sutisa focused on the learning environment, and Kamonwan decided to deal with all three aspects and was the first to try to connect the three practices together.

Throughout the ABI implementation phase, the teachers' views of learning seemed to move back and forth between old and new ideas. However, by the end of the semester the teachers in this group appeared to stabilize their practices after finding that the ABI approach worked in promoting students' voices and social interactions in the classroom. This observation aligns with other studies (e.g. Guskey, 1986; Huberman & Miles, 1984; Arora et al., 2000; Hand & Treagust, 1997) which have found that teachers sometimes need to try a new practice until they discover that it results in a satisfactory outcome such as good progression in student learning. The teachers then began to shift their beliefs as well as their practices toward the new learning approach.

The non-shifting group initially was not opposed to the constructivist learning approach; however, even though these teachers were able to explain their understanding of the significance of inquiry learning, they also expressed ambiguity toward the approach. Between the two teachers, Nattawee started the process with a better understanding of inquiry learning than Kritt. She also expressed a positive attitude toward the approach and retained that attitude throughout the semester. However, she did not transfer her positive attitude to a willingness to implement the theory in practice, and finally decided not to use the ABI approach in her classroom.

These teachers' beliefs appeared to differ from the intended meaning of inquiry-based learning. In this case, it was difficult for the teachers to work smoothly and get through problems since they started with uncertainty about the newly presented knowledge (Fraser, 1998; Kelly & Staver, 2005; Roehrig & Kruse, 2005; Wallace & Kang, 2004). While this is not unexpected, this study suggests that developing teachers' understanding of and orientation to the core idea of the new approach is a priority that should be emphasized, as it drives the stable and effective implementation of other steps (Dexter, Anderson, & Becker, 1999; Wetzel, 2001; Schwarz et al., 2003).

Factors that Translated the Alignment of Teachers' Views
of Learning and Teaching Practices

Even though teachers' beliefs and practices are interrelated, sometimes their alignment is not linear (Marx et al., 1997). In real situations, teachers may sometimes need to transform their practices in a different way than their beliefs due to a variety of influencing factors (Tobin, Tippins, & Gallard, 1993; Wetzel, 2001; Prawat, 1992). As illustrated in Nattawee's case, even though she agreed with the effectiveness of student-centered learning, she had encountered dilemmas in her cultural context, such as peer-teacher pressure, pressure from parents, and the need to respond to students' goals, that turned her beliefs toward teacher-centered practice.

Contrary to the non-shifting group, when faced with the same barriers, the teachers in the shifting group appeared to make more of an attempt to deal with problems. For example, Ausanee mentioned the barriers of implementing inquiry in her classroom, such as a lack of materials and time constraints. Rather than giving up, she indicated her willingness to adjust her teaching, saying, "We might try more technique such as learning in groups, group discussions, or assigning students to brainstorm ideas to promote their critical thinking" (Ausanee: RI, 8/6/12).

In this study, every teacher agreed that they were concerned about the materials and curriculum to be covered. This is a general concern of teachers (Gallagher & Tobin, 1987). This difficulty impacted how these teachers designed their lesson plans, used questions in the classroom, and conducted inquiry activities. However, the shifting group did not appear to be threatened by its concerns. Rather, the teachers in this group thought this was challenging and tried to do their jobs while also dealing with barriers such as curriculum and testing. These barriers did not affect their change toward reformed learning except in the case of Sutisa, who struggled to maintain her implementation but exposed her willingness to get through the problems. On the other hand, the non-shifting group was unable to overcome the barriers; these teachers did not even try because they were blocked by their concerns.

In conclusion, every teacher had to overcome some challenges. The difference was that the shifting group had a positive attitude toward the new approach and exhibited a willingness to engage with and experience the ABI teaching practices. Therefore, they were able to move forward in the shifting process. In comparison, the non-shifting group had no willingness to shift; they were aware of the barriers and decided not to implement the theory in practice. Willingness thus appeared to be a key factor in driving teachers to implement an innovative teaching approach. Hence, the results of this study suggest that teachers' attitude to change may be a factor in helping the movement from an initial challenging of their views of learning to the change in practice.

The Relationship of the Change among the Three Observed Criteria

The three teachers in the shifting group shared a similar trend of using questioning, problem solving, and the establishment of a supportive learning environment in their classrooms. At the conclusion of the study it was observed that the teachers in the shifting group had changed their teaching characteristics as follows:

- The teachers developed a higher level of questioning that asked students to practice judging rather than just aiming for the recall of information;
- Teachers' questioning targeted more than just leading students to the right answer; it also emphasized students' reasoning, critical thinking, and problem solving skills;
- Teachers' class activities focused more on cognitive thinking and problem solving skills such as graph interpretation and reasoning scenarios, asking students to brainstorm and construct explanations rather than just focusing rote learning;

- Teachers were more thoughtfully concerned with creating their classroom environments to develop students' voices and encourage class interactions such as group work and student presentations; and
- The teachers designed class activities to be more challenging and interesting by adding social interactions and asking students to explain their solutions, not just assigning them to work on individual problem-solving like they had usually done before.

Even though the three teachers in this group all started with different practices, each teacher eventually implemented the three observed criteria in their classes. These criteria were utilized in ways that supported each other and boosted inquiry activities to function more effectively in the classroom context. For example, the teachers used questioning as a strategy to engage students' learning and develop their critical thinking and problem solving skills. At the same time, they also created classroom environments that were aligned with inquiry investigation by using different types of learning, such as brainstorming, employing multimodal representations, and using mathematical formulas to convey ideas. In addition, the teachers also experimented with a variety of classroom settings to boost students' social interactions, such as small group, group to group, and whole class learning. Thus, questioning, problem solving and reasoning, and the learning environment all appeared in the classes of the shifting group, as shown in figure 5-1.

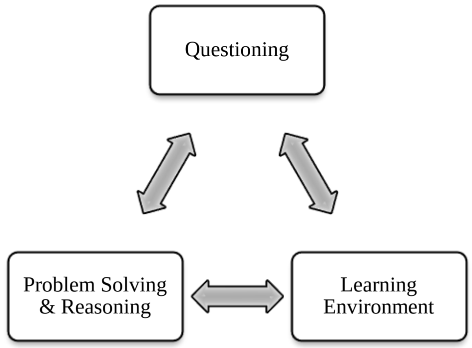

Figure 5-1 The Relationship Among the Three Observed Criteria

However, the degree of connection and frequency with which these practices were used were totally dependent upon the specific situations and the way the teachers designed their lessons. The connection among the three criteria was more visible during the final two months of observation in the shifting group's classes. Many times the teachers used various questions along with a problem solving activity, while at the same time creating a welcoming learning environment for students to discuss and negotiate ideas while they collaborated during the class activity.

On the contrary, the teachers in the non-shifting group used questioning to ask for short answers and used this practice to lead their students to the right answer rather than asking for their reasoned explanations. In addition, the teachers in this group mostly emphasized individual problem-solving activities; there were just a few times when they asked students to work in groups. Thus, it was rare to observe a relationship between the three criteria in these teachers' classes.

Major Assertions Arising from the Study

Two assertions are proposed as an outcome of this study. They are related to the study's unique cultural setting and involve the shift in the large class size and its change process.

Assertion 1: In the large class size cultural setting, teachers' positive attitude and their willingness to implement the new teaching approach impacted the shift in their views of learning and teaching practices.

Normally, a Thai school has large class sizes, and thus this is a big difference from the context of other studies. Such a contextual situation can make it difficult for teachers to handle students' miscellaneous behaviors, conduct inquiry activities in their classrooms, and promote a change from traditional instruction to student-directed learning. To provide a sense of how the teachers could deal with this difficulty, the first assertion of this study is associated with the shift in teachers' views of learning and pedagogical practices in the large class size cultural setting.

Due to the number of students in each class, the idea of adopting a reformed learning approach, from a belief standpoint, may be difficult to handle and not visible to teachers. Thus, the results of this study indicate that the shifting group teachers were willing to engage first with changing their practices. However, these teachers also had a positive attitude toward engaging with and having discussions about the learning theory, and a connection between belief and practice was observed; the two were not pulling in different directions. As illustrated in the case of the shifting group, each of the teachers held a positive perspective of the ABI approach that led them to try its practices. When they found that the new approach made sense to them, they moved forward to the implementation phase.

The teachers' willingness to engage with the new experience as well as to get through the problems within their school setting was another crucial factor influencing their shift in views of learning and teaching practices. The teachers in the shifting group expressed an optimistic attitude toward the new learning approach. They were able to see ways to work through the curriculum and some of the classroom management barriers. Hence, they were not overly bothered with those matters. In other words, the teachers actually recognized the concerns and were able to see how to deal with them. On the other hand, the non-shifting group saw these concerns as barriers and did not want to engage in the implementation process.

In the large class size circumstances of the Thai classroom, emphasizing practice may be a better start for teachers to experience the reformed learning approach than dealing with learning theory. It may be that teachers first need to be challenged with the major theories and knowledge about the reformed learning approach, but they also need to have space for practice. The change process is explained in detail in the following section.

Figure 5-2 was created based on the results of this study. Four of the five participants held a positive perspective and one had a neutral attitude about the ABI approach. This figure displays the fact that sometimes a teacher's positive attitude may not be transferred to an unwillingness to implement the new teaching approach.

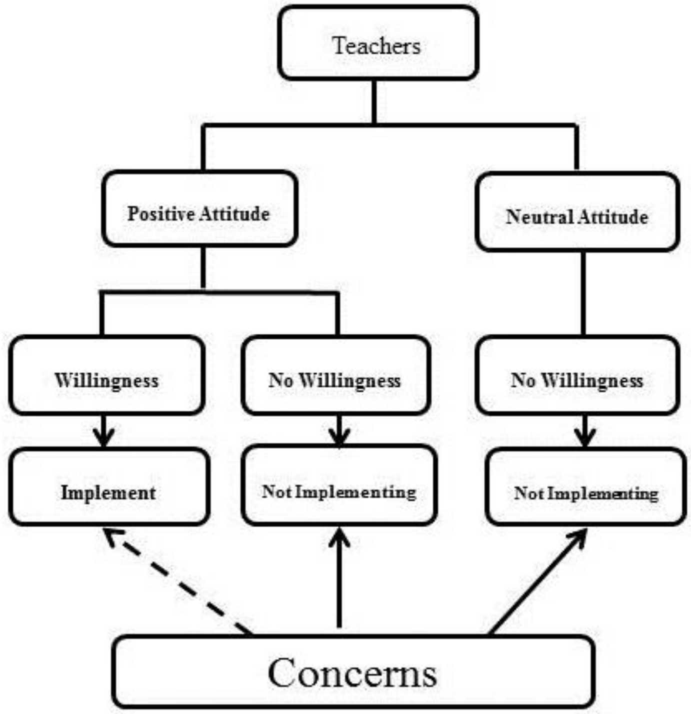

Figure 5-2 The Translation of Teachers' Attitudes toward the New Learning Approach to their Teaching Practices

Generally, the teachers in both groups had concerns, and these concerns were similar, involving issues such as curriculum, testing, or the lack of academic resources. However, even though every teacher had the same set of anxieties, the teachers from the shifting group and the non-shifting group presented different methods and ideas to deal with their concerns. As shown in figure 5-2, the teachers from the shifting group who had a positive attitude toward the reformed learning approach transformed these perspectives into a willingness to be engaged and challenge their practices. Hence, they tended to have the power to implement the new learning approach (Bray-Clark & Bates, 2003; Allinder, 1994; Haney, Czerniak, & Lumpe, 1996). Furthermore, they were better able to endure the barriers or stressful situations (Bandura, 1997).

Even though they expressed their theoretical knowledge of inquiry learning, the teachers in the non-shifting group conveyed a different attitude toward this approach. For instance, Kritt's attitude toward ABI was neutral, but despite that he could not overcome the barriers and did not attempt to translate the theory into practice. For him, implementation of the new approach did not occur.

Barriers did not only impede the teacher with the neutral attitude; the study also showed that Nattawee, who at first expressed a positive view of inquiry learning, also did not transform her ideas into practices. At the beginning, Nattawee mentioned inquiry's effectiveness, commenting that it promoted students' knowledge construction, and this idea seemed to make sense to her. However, she did not employ this knowledge in her practice as she had planned. The activities she constructed for her class did not qualify as inquiry activities where students had authority to perform their own learning or negotiate their ideas in public. And although Nattawee mentioned that she intended to decrease her role in the class, she was not able to accomplish this and continued to direct her students in how to work through the problems. The researcher believes that Nattawee did not link her positive attitude about inquiry learning to her willingness for implementation like the teachers in the shifting group. The teachers in the non-shifting group were more sensitive to the barriers they faced and therefore ultimately did not translate their positive or neutral attitudes into moving their practice toward reformed learning.

In summary, the study found that the participating teachers held similar theoretical ideas about teaching and learning. Nonetheless, without a willingness to change those ideas, a positive attitude and accumulated knowledge may not be a solid enough foundation to drive teachers to implement reformed learning. This is illustrated by the shifting group, in which the teachers started with a positive attitude toward the new learning approach and then expressed their willingness to try implementing the ABI approach in their classrooms; after doing this they finally started to shift their practices.

Thus, this study suggests that teachers' positive attitudes and willingness are connected to the shifting of practice and are necessary for change.

Issue Arising from the Study

As highlighted in the literature, self-efficacy is an important factor in supporting teachers' confidence in their teaching ability, positive attitude, and willingness to implement a new teaching approach (Bray-Clark & Bates, 2003; Guskey, 1988; Hoy & Woolfolk, 1990; Ghaith & Yaghi, 1997; Gibson & Dembo, 1984).

Although this study did not measure self-efficacy, it appears to the researcher that it may have positively influenced teachers' positive attitudes toward and willingness to implement a new teaching approach (Guskey, 1988; Ghaith & Yaghi, 1977). Self-efficacy may have worked in tandem with a positive attitude toward the ABI approach to increase teachers' willingness to perform the shift in their teaching practice in the classroom. At the same time, those factors diminished teachers' concerns and pushed them to implement the innovative teaching approach (Posnanski, 2002; Czerniak & Chiarelott, 1990; Westerback & Long, 1990).

Similarly, a lack of self-efficacy may have negatively influenced the teachers' willingness to implement a new teaching approach. Kritt, a non-shifting group teacher, sometimes mentioned that his limited teaching experience made him unable to conduct effective questioning in his class; furthermore, he sensed that the students were having a hard time understanding his questions. Similarly, Nattawee sometimes reflected uncertainty in her own pedagogy, suggesting that it might not be strong enough to support her students to become self-learners; thus, she sometimes still nourished them via information transfer. These comments may reflect the low self-efficacy of both teachers in this group, as they felt doubtful in their abilities to support student-directed learning and to work on this approach. Hence, this might be another factor that influenced teachers' unwillingness to engage with constraints and continue with the implementation process, even if they initially displayed a positive attitude toward the new learning approach. As opposed to the non-shifting group, the three teachers in the shifting group expressed their confidence in their understanding of inquiry and their physics content knowledge. This may reflect a high self-efficacy that made them feel challenged by the new learning approach and the implementation process rather than being threatened or concerned by it like the other group.

Therefore, there appeared to be a strong connection between teachers' self-efficacy, positive attitude, and willingness. This point raises critical and interesting questions for the researcher that may become part of further research to explore the connections among these issues. Future research could also investigate these critical factors to explain the difference between teachers in the shifting and non-shifting groups. In this light, the difference between the groups might occur due to their self-efficacy, as it could be a potential determining factor in the changing process.

Assertion 2: Classroom practice time and reflective time were key in promoting the teachers' change in this study.

The Change Model

The theory of 'Conceptual Change' (Posner et al., 1982) explains that people normally use their current ideas to deal with new situations in a process called 'assimilation.' In a new situation where the existing idea doesn't work well, it is possible for a new idea to be adapted, a process that is called 'accommodation.'

In the big picture among the five participants of this study, teachers sometimes moved back and forth between old and new ideas while teaching. The difference was that the shifting group put more effort into implementing the ABI learning approach by providing more time for students' voices, while the other group made fewer attempts to do this. Figure 5-3 explains the process of change in the shifting group.

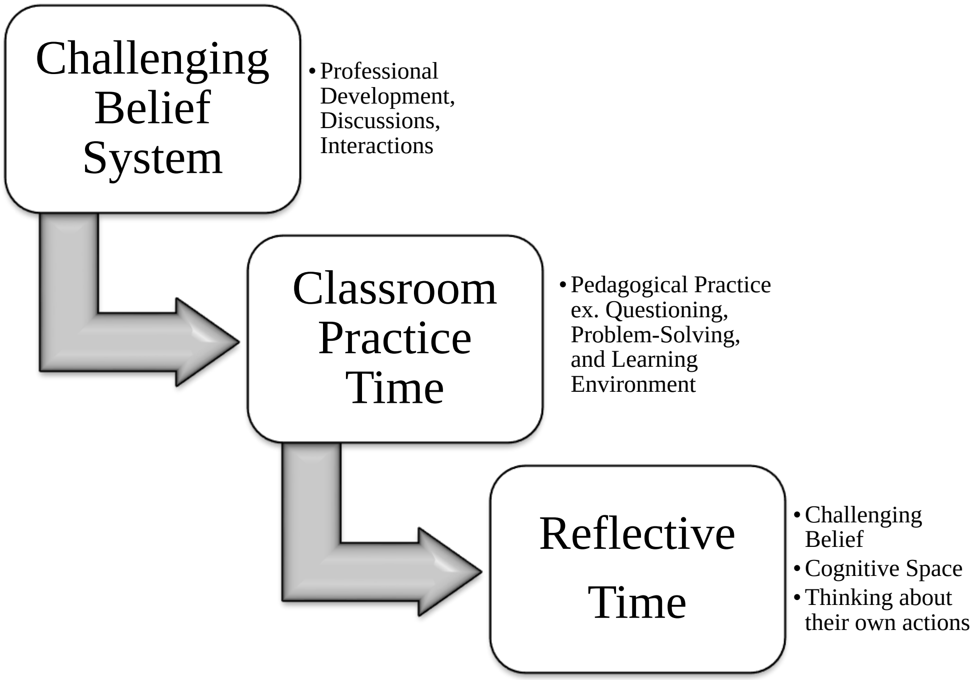

Figure 5-3 The Change Model of the Shifting Group

Challenging Belief System

As part of the initiation of change, professional development (PD) is a significant stage for teachers because this is the stage in which they are required to challenge their existing ideas. Generally, the process of any professional development activities is meant to induce a change in teacher beliefs, attitudes, and classroom behaviors (Guskey, 1986). As stated by Atkin (1996), teachers' pedagogical practices are aligned with their views of learning. For instance, if teachers believe that they have authority in the classroom, their practices may be aligned with this belief, which will result in them being information transmitters. In addition to the constructivist view of learning and the idea that learning involves conceptual change, learners can construct their own knowledge and conceptual change can occur through negotiation as part of the learning process (Posner et al., 1982). Thus, 'negotiation' can be used as a tool to drive 'accommodation.'

The shifting model then began with the initial phase where the teachers were challenged to reflect on their own ideas about learning. The belief-challenging phase occurred during the professional development workshop and during the discussion and interaction sessions. As mentioned previously, people need to become dissatisfied with their existing ideas, because if they do not they will not even think about modifying or replacing their old ones (Posner et al., 1982). Therefore, the initial activity of the PD centered on getting teachers to assess what they know, as this process enabled them to 'understand what they understand.'

Negotiation plays a key role in this process. During the PD workshop the teachers were provided multiple opportunities for negotiation. At first they were required to negotiate internally—that is, to think about their existing beliefs and skills. The stage was then open for them to socially negotiate with others. This challenging step may lead teachers to seriously question who they are and what they do. At this point, some teachers who had previously favored the traditional teacher-centered approach may become dissatisfied with that and adopt an inquiry approach if they find the inquiry approach makes sense and is reasonable, accessible, and applicable. Thus, it is important that teachers have opportunities to negotiate within themselves and with others (as learning has a private and a public component) throughout this process to promote 'accommodation.' Although the negotiation process will not always make teachers change their ideas, it will help them to develop skills in social negotiation since knowledge not only resides in the individual but also exists at the social level. The teachers gain knowledge from negotiating with others, how they, in the end, agree or disagree with the social commitment. They go through the motions of constructing and testing their own ideas, communicating them to others, and negotiating privately and publicly.

After being challenged, teachers were led to the disequilibrium stage where they were provided opportunities to become dissatisfied with their existing mental schema.

However, this was just a starting point; teachers could either engage with this process or choose not to. Thus, participating in the initial step does not necessarily mean that a shift will occur in teachers' preexisting concepts; although the presented ideas may be useful, they may not have meaning for the teachers. In this case, the teachers need to explore further whether the new idea is better than their existing, albeit unsatisfactory, one.

Classroom Practice Time

Following this initial process, teachers may need to be pushed further to the next step, which is 'plausibility' (Posner et al., 1982). This stage is more convincing because it concerns ideas that people can realistically achieve, and it is likely to be applicable to a broader range of scenarios.

Even though the PD begins to focus on shifting learning theory, it may also highlight getting teachers to shift their practices, because the shift in ideas sometimes does not occur until teachers start to change their questioning patterns, emphasis on student-centered activities, and classroom environments. Thus, the next step is 'Classroom Practice Time.' In this stage, teachers would challenge their practices by experiencing the reform-based pedagogical practices, such as using a variety of questioning approaches, creating diverse inquiry problem-solving activities, and establishing a supportive learning environment like including group work. This phase would provide opportunities for teachers to explore the world where they could work on the problem and examine the possibility of using the new knowledge to replace their old ideas.

In this study, the three teachers from the shifting group and one teacher from the non-shifting group tried to adopt the new approach in their classroom practice as they provided class time for inquiry activities and student discussions immediately after attending the workshop. This may suggest that these teachers challenged their practices by providing themselves with 'Classroom Practice Time' to enact the ABI approach.

However, this changing action could have occurred either from an actual interest in this approach or from simply wanting to test its possibility. Additionally, while four of the participating teachers decided to give themselves space for practice time, the fifth teacher was from the non-shifting group, and this teacher decided not to provide time in class for his students to work in groups or practice inquiry activities. Instead of offering himself a space to practice, figure out his own way to perform the teaching, or engage with the new learning approach, the teacher preferred to obtain a good teaching manual that he could follow.

Reflective Time

Besides allowing time and space for practice, reflective time is another crucial step. This step is about reflecting on how the new concept can be applied or extended further. It is not a given that every teacher who provides practice space will also engage in reflective space where they will examine their actions within the classroom. From the study, it appeared that some teachers only provided physical space for their pedagogical work in which they allowed students to work in groups; after finishing the activity, however, the teachers did not reflect on what they did and how it worked. In this case, teachers made use of practice space but did not challenge their own cognitive thinking or provide the cognitive space necessary to reflect on their changing actions.

At the beginning of this study the teachers in both groups did not have large differences in terms of practice scores, but over time the shifting group's practice scores continuously increased. The teachers in the shifting group gradually changed their practices and views of learning toward the reformed learning approach after they had tried to adjust their classroom environment by providing more time for students to talk and conducting problem-solving activities to encourage student participation. Their willingness to enact these activities was maintained throughout the study. Thus, over time their classrooms became more student-centered. Importantly, these teachers were the ones who also gave themselves cognitive space to think about what they had done. After this, they mentioned that they were not worried about the curriculum and the national test. In addition, some of their ambiguities related to the implementation of the ABI approach, such as doubt regarding the students' ability to negotiate ideas as well as uncertainty about students' skills for thinking, reasoning, and constructing their own knowledge, gradually diminished.

After attempting the classroom practices and observing students' progression, the shifting group teachers realized that students could perform their own learning and were able to negotiate and communicate their ideas in public. The three teachers reflected that they felt good about finding out that the students were able to explain phenomena by themselves with less guidance from their teachers. Furthermore, they were excited to see that the students enthusiastically participated in activities and answered class questions. This revealed that the teachers had a stronger belief in the values of the ABI approach for promoting students' learning abilities and increasing their voices in class. The teachers became more confident in transforming their role from content deliverers to supporters or collaborators, and were willing to continue improving themselves through the implementation process. The reflective space was key in promoting the teachers to open their minds and connect their practices to the theoretical ideas. It was also a fundamental process for initiating a change in their views of learning and practices.

Contrary to the shifting group, one of the non-shifting group teachers did not change from his normal practice. He did not provide time in class for questioning or completing group work, and he did not want to continue with the implementation phase. In this case, the teacher did not want to provide the students with classroom space to practice the new approach or give himself cognitive space to revisit whether his ideas had changed. The other teacher in the non-shifting group did provide some practice time but did not give herself her own reflective space to think about whether this approach was valuable or not. While the teachers in the shifting group found their own ways to adapt the ABI approach to suit their classroom circumstances, those in the non-shifting group were blocked by their concerns.

In conclusion, the focus on teachers' cognition and practice is important for making a substantial change in teachers' beliefs and practices toward the reformed learning approach (Richard, 1990). To promote a shift in teachers' views and practices toward the argument-based inquiry approach, it is important to provide opportunities for them to immerse themselves in a collaborative environment where they obtain experience in sharing and negotiating ideas with others. Authentic experience is essential since the realization and accomplishment will never occur if teachers just receive an idea without a chance to practice by themselves in a real classroom setting (Arora et al., 2000; Krajcik et al., 1994; Peers et al., 2003; Davis, 2003). In addition to practice, teachers should also have time to reflect on their own existing ideas, examine their practices, and think about their concerns. Doing this could possibly trigger thinking and consideration of implementing the reformed learning approach, making it possible that the change can finally occur.

Limitations of the Study

As this study spent only about fourteen weeks observing the shift in teachers' views of learning and teaching practices, it was outside the reach of the study to expect a full transformation in the teachers' approach to pedagogy. Continuously observing this group of teachers for a longer time may reveal more detailed descriptions of the factors that promote the teachers to implement the new learning approach or the barriers that prevent this change from occurring. In addition, a longer investigation including observation of different lesson units may be worthwhile in providing a different or broader aspect of teachers' change compared between units. However, this study focused on the beginning phase of ABI implementation in which teachers were considering, deciding, or beginning to shift their beliefs and practices. Thus, the study obtained critical points about how to get teachers moving toward the argument-based inquiry learning approach.

The second limitation was related to the variation in the participants. This study observed five physics teachers, a sample which might not be wide-ranging enough to generally represent Thai teachers' change. However, this is a qualitative study and its nature is to examine by focusing on the phenomena in great detail. Enlarging the number of participants or expanding the scope of the study by recruiting teachers from other subjects and different teaching levels may reveal slightly different results.

The third limitation involved the short duration of the professional development workshop. Due to the teachers' availability, the study could offer only a one-day academic workshop. However, the teachers were fully introduced to the new teaching approach and gained experience practicing the new learning strategy in that they were challenged to discuss, come up with their own questions, critique, and share their ideas with the group. Having more time to discuss theory and practice in class might serve to help teachers gain more understanding of the essence of the ABI approach and thus may affect their implementation of this approach in the classroom.

The fourth limitation has to do with the study's subjectivity. Due to the nature of a research study that tracked how teachers' views of learning and practices changed across the observation period, it was impossible to avoid interactions between the researcher and the participants. As Hatch (2002) mentions, all knowledge is subjective and it is impossible to produce a purely objective research study. However, this study tried to eliminate the biases that might occur by utilizing multiple data sources to explain the study's phenomena as a way to contribute to triangulation (Patton, 2002; Denzin, 1978; Stake, 1995).

Implications

Argumentation or negotiation is still a theoretical idea for many teachers, particularly teachers who are familiar with the didactic teaching orientation. It is also an abstract idea for people who have not learned how to practice it in other situations, and thus the argument-based classroom, replete with dialogic interaction, takes some getting used to (Mercer et al., 1999). The question is how to learn and/or use the argumentation approach in a scientific context.

As this study investigated teachers' views of learning and their pedagogical practices, the beginning step to promoting change has been examined. The next questions to think about are how to use these emerged outcomes to maximum value for further implementation. Another important issue to consider is that as claims and evidence are used as the components of argument and explanation, how can evidence be meaningfully used to construct explanations and how can teachers promote this idea in their science classrooms? The implications of this study are the final component of this chapter; they are divided into two areas: implications for professional development and implications for future study.

Implications for Professional Development

Argument may be a new approach for many science educators, teachers, and students. Thus, in order to successfully apply this approach in a science classroom, it is first necessary to help all participants understand the concepts and the processes involved. The professional development programs, academic workshops, and long-term collaborative inservice programs come to play significant roles here in order to support teachers' changing beliefs and practices (Richardson et al., 2001). Results from this study suggested that all academic supports should primarily pay attention to teachers' views of learning and their understanding of inquiry-oriented instruction by challenging or engaging teachers' ideas of learning in a way that enables them to consider how to shift their practice. By doing this, teachers will be more flexible in implementing and suitably adapting inquiry to their classroom environments in a way that makes sense to them.

In addition, this study noted that it takes time before teachers can decide whether or not they should employ a new theoretical idea and bring it into practice. The teachers in the shifting group of this study began to try the ABI approach by taking action immediately after they had been introduced to this approach; at that time they did not know whether it would work. Thus, teachers need sufficient time to experience an innovative approach, particularly at the beginning of the implementation process, since at that point they are still undetermined as to whether or not they should move forward with the new approach. During this process, it is necessary that teachers obtain opportunities to practice with all related skills and to develop their cognitive thinking, which can be advanced through discussion and communication with their peer teachers, co-workers, or professional developers.

The significance of offering teachers the time space to practice is also reinforced by other studies (e.g. Richardson, 1990; van Driel, Beijaard, & Verloop, 2001). These studies indicated that providing time and opportunities for teachers to learn, discuss, and perceive the value of the new teaching approach by themselves would promote their conceptual growth, enhance their understanding of the essence of the new approach, as well as allow them to construct their own knowledge with the new idea. This implication may be useful for professional developers who are trying to encourage or support teachers to work through reformed learning. The developers need to make sure that teachers have gained enough support, authentic experience, and adequate time for attempting the implementation. If the teachers do not ascertain the essence of the new approach by themselves, they may not realize its value and may not be able to apply the knowledge to their classrooms.

In addition, as discussed previously in the shifting model (figure 5-3), the study suggested that future professional development should emphasize both belief and practice challenges. However, one model of shifting cannot be systematically applied to all teachers since each teacher is different. For some teachers, it may work to begin with challenging their beliefs; some may prefer to start with challenging their practice; others may choose to challenge both parts simultaneously; and some may desire to challenge one over the other. For instance, this study appeared to contain three teachers that were willing to engage with both spaces by beginning with one over the other. One of the teachers began to engage just one of those spaces, her practice, but because she was hindered by concerns she did not continue to the reflective process; thus, no shift occurred in this case. The final teacher in the study did not engage in any of those spaces.

Again, each teacher is different and there is no one definitive model of shifting that can be applied to all teachers. Therefore, in order to promote teachers to shift their beliefs and practices toward an innovative learning approach, it is essential that educators or professional developers emphasize the physical and cognitive spaces. However, they need to be flexible with the implementation process and understand that each individual has their own authority to choose and perform their beliefs and practices in their own way.

Implications for Future Study

Educational systems have been gradually shifting away from teacher-centered learning toward a constructivist orientation (NRC, 1996, 2000). To stimulate this change, this study suggests that it is necessary for the researchers to better understand how teachers view learning, how learning takes place, how a science classroom can be a supportive resource to purposefully drive the inquiry process, what difficulties teachers encounter, and how to help teachers get through these barriers. These are crucial issues to consider, particularly when investigating teachers' adopting an innovative teaching approach in their classroom (Tobin & LaMaster, 1995; Yerrick, 1995; Parke & Nugent, 1997).

As mentioned in Chapter 1, the studies conducted in an Asian context, where the science classrooms have typically used lecture-based instruction, are limited. Thus, this study aims to fill the gap in the literature on the shift of teachers' views of learning and teaching practices toward student-centered reformed education, with particular emphasis on the Thailand educational context. In order to move the Thai educational system toward the ABI approach, more research studies need to take place that investigate teachers' views of learning and teaching practices in various aspects and broader views because this is a foundational idea for effectively pushing an innovative learning approach to occur. This study suggests that future research go further into the larger context by expanding the number of participants, enlarging the study to other subjects, and expanding the study to other grade levels.

As former studies have suggested it would take about eighteen months to three years for teachers to noticeably shift their practices and begin to understand the essence of the new teaching and learning approach in their classrooms (Martin & Hand, 2009; Blumenfeld et al., 1994; Huberman & Miles, 1984), another point for future research may be to consider conducting a longitudinal study. In this case, the full transition of teachers' beliefs and practices may be revealed.

In addition, this study found that teachers' attitude, willingness, and practice were interrelated. Thus, it would be valuable to obtain more participants and begin to examine the relationship among these criteria. Such a study would enable a richer understanding of the change in using these components to find out which space is important for teachers to work on.

Thus, future studies may continue to investigate:

1. What is the relationship among teachers' attitude, willingness, and practice?

2. What spaces should teachers work on—practice space or cognitive space? Which should go first? Would they go individually, simultaneously, or hierarchically?
3. How should professional developers challenge teachers, via their practice or cognitive space?

Last but not least, many times teachers complain about the difficulty of aligning their teaching with the new curriculum. With this issue, it is necessary to encourage teachers to think differently in that this shifting is not about content but is rather about concepts that they should pay attention to. Researchers might need to explore means of helping teachers to deal with or overcome barriers of curriculum and time management, which are the issues teachers comment on most frequently, to be able to see the benefits of the new learning approach. Hence, this may be another implication for further studies.

APPENDIX A

TEACHER LESSON SEMI-STRUCTURED INTERVIEW

Before Classroom Observation

1. Could you briefly describe today's lesson?
2. What subject matters or concept do you expect students might have difficulties with today? Why do you think so?
3. What kinds of things do you take into consideration in planning this lesson?
4. How will you be able to know whether you students understand the concepts you try to teach today? What evidence are you looking for that students have been successful in addressing the goals for the lessons?

After Classroom Observation

1. How do you feel about the lesson today?
2. Tell me about any assignments or activities that you used in the lesson.
3. Tell me about what you thought the students got out of the lesson.
4. What do you consider the most effective teaching moment was in the lesson? Why? How did you achieve? Why did it work? What signaled you that students were learning?
5. Are there any things you want to change of today's lesson?
6. Do you have any concerns/difficulties according from this class? Any solutions you can come up with?

Source: Horizon Research Inc. Instruments Teacher Interview Protocol Observation and Analytic Protocol Mathematics and Science Questionnaire)

APPENDIX B

TEACHER REFLECTION SEMI-STRUCTURED INTERVIEW

Learning

1. What does learning mean to you? How do you define learning?
2. What do you think it is the most important of learning in you classroom? How do you know that learning occurs?
3. What is the role of questioning in learning?
4. How do the students learn? How do students store their knowledge?
5. Learning is to give information to students or promote them to construct knowledge, what do you think?
6. What do you think when people say, *"Learning to think is learning to argue* (Osborne, Erduran & Simon, 2004, p. 141)?"

Pedagogy

1. What is the strategy do you think it is appropriate to teach physics?
2. Which teaching strategy does you existing use? How does it work? Anything you prefer to modify?
3. Is your teaching technique proper to promote students to construct their own knowledge? If not, anything to modify or change?
4. What is your role to align with the student-centered learning?
5. Do you use questions along with your lesson? What kind of questions do you use? Why?
6. What does the learning environment in your class look like? In your opinion, what is appropriate learning environment to promote the learning? How do you do to support?
7. So far, what is your concern/difficulty you experience implementing the argument-based inquiry approach? Any possible solutions you can come up with?

APPENDIX C

STUDENT SEMI-STRUCTURED INTERVIEW

(MODIFIED FROM THE REVISED R-TOP)

1. What does learning mean to you? What is your learning goal?
2. What is the teacher's characteristic in your classroom?
3. Are there any changes you notice, occurring throughout this semester in terms of the teacher' teaching strategy, his/her supports, or opportunity for you to talk or present ideas?
4. Does the teacher provide opportunity for you to talk among friends, how?
5. Does the teacher act as a resource person, working to support and enhance your investigations, how?
6. Do the lessons the teacher provided encourage you to seek and value alternative modes of investigation or of problem solving, how?
7. Does the teacher provide you a chance to reflect about your learning, how?
8. Does the teacher challenge you to think, how?
9. Does the teacher encourage you to participate in the investigations or classroom activities, how?
10. Do the teacher's questions trigger divergent modes of your thinking, how?

APPENDIX D

PLAN FOR THE ONE-DAY INSERVICE PROFESSIONAL DEVELOPMENT WORKSHOP

Argument-based Inquiry Workshop Tentative Program

May 26th, 2012

(For Physics Teachers)

- What are Learning, Teaching, and Science?
- How is Language related to Science?
- What is inquiry approach to teaching and learning?
- Problem based learning design and implementation
- Questioning techniques
- Establishment of a supportive learning environment
- Discussion on inquiry-based curriculum development
- How can an Argument-based Inquiry Approach be linked to Thai curriculum?
- Teacher's concerns on implementation process

Time	Content / Activity	Materials & Givens
8:00– 8:45	Introductory Activity - Participant Pre-Conceptions (What is Teaching, Learning, Science) - Participants explore fish - Participants discuss / debate what is causing fish to act the way it does - Discussion – Teacher Actions vs. Student Actions - How was this "science", "inquiry"?	- Fish - Poster Board
8:45 – 10:00	Teaching & Learning Discussion - What is learning? Teaching? - How do we come to know things in Science? - What are critical aspects of science? - What is role of language in science? - How do we frame teaching around big ideas and negotiation? - Mr. Xavier activity—the introduction to "Question, Claim, Evidence".	
10:00 – 12:00	Continue on the Fish activity - Questioning techniques – what makes	- Fish - Poster Board

Time	Content / Activity	Materials & Givens
	question good? - Tests & Observations - Record, Present, Discuss - Claim Generation & Evidence to Back Up - Critique of Data & Procedures	
12:00 – 1:00	Lunch	
1:00 – 2:15	Thai physics curriculum & Inquiry-based approach - Discussion on inquiry-based curriculum development	
2:15 – 2:30	Break	
2:30 – 3:45	Inquiry & Pedagogical Shift - Necessary Teaching Skills & Management Discussion (Teachers' idea how to conduct good questioning, problem solving, and establishing a supportive learning environment) - Links between inquiry approach and teacher actions Teachers Share Ideas	- Poster Board
3:45 – 4:00	- Teachers' concerns - Wrap Up & Questions	

APPENDIX E
CLASSROOM OBSERVATION GUIDELINES

Teacher……….……………Date…………………………..		
Category	Observed Criteria	Researcher's Field note & Comments
PROBLEM SOLVING & REASONING	1. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	
	2. Students used a variety of means (models, drawings, graphs, symbols, concrete materials, manipulative, etc.) to represent phenomena (quantity and time with materials).	
	3. Students were encouraged to generate conjectures, (or) alternative solutions, and/or different ways of interpreting evidence.	
	4. Active participation of students was encouraged and valued.	
	5. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures (quality).	
	6. Students were reflective about their learning (what do you think, and how do you know).	
	7. Intellectual rigors, constructive criticism, and the challenging of ideas were valued (debating ideas).	
Comments		
LEARNING ENVIRONMENT	8. Students were involved in the communication of their ideas to others using a variety of means and media (variety of types and scales of delivery).	
	9. The focus and direction of the lesson was often determined by ideas originating with students.	
	10. There were a high proportion of student talk and a significant amount of it occurred between and among students (quantity of interactions).	
	11. Student questions and comments often determined the focused and direction of classroom discourse (quality of student interactions).	
	12. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	
	13. There was a climate of respect for what others had to say.	
	14. The Lesson was designed to engage students as member of a learning community.	
	15. In general the teacher was patient with the students (mostly about the time).	
	16. The teacher acted as a resource person, working to support and enhance student investigations.	
	17. The metaphor "teacher as listener" was very characteristic of this classroom.	
Comments		
QUESTIONING	18. Questioning to encourage student's investigation	
	19. The teacher's questions triggered divergent modes of thinking	
	20. Teacher's questioning to promote students' negotiation and multi-person conversation	
	21. Opportunity for leaners to pose their own questions	
Comments		

APPENDIX F
THE RTOP SCORING TEMPLATE

Teacher. …………………Date of recording…………………………….			
Category	Observed Criteria	Score (0-4)	NOTE
PROBLEM SOLVING & REASONING	1. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.		
	2. Students used a variety of means (models, drawings, graphs, symbols, concrete materials, manipulative, etc.) to represent phenomena (quantity and time with materials).		
	3. Students were encouraged to generate conjectures, (or) alternative solutions, and/or different ways of interpreting evidence.		
	4. Active participation of students was encouraged and valued.		
	5. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures (quality).		
	6. Students were reflective about their learning (what do you think, and how do you know).		
	7. Intellectual rigors, constructive criticism, and the challenging of ideas were valued (debating ideas).		
LEARNING ENVIRONMENT	8. Students were involved in the communication of their ideas to others using a variety of means and media (variety of types and scales of delivery).		
	9. The focus and direction of the lesson was often determined by ideas originating with students.		
	10. There were a high proportion of student talk and a significant amount of it occurred between and among students (quantity of interactions).		
	11. Student questions and comments often determined the focused and direction of classroom discourse (quality of student interactions).		
	12. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.		
	13. There was a climate of respect for what others had to say.		
	14. The Lesson was designed to engage students as member of a learning community.		
	15. In general the teacher was patient with the students (mostly about the time).		
	16. The teacher acted as a resource person, working to support and enhance student investigations.		
	17. The metaphor "teacher as listener" was very characteristic of this classroom.		
QUESTIONING	18. The teacher's questions triggered divergent modes of thinking (by students).		
	19. Questioning to encourage student's investigation		
	20. Teacher's questioning to promote students' negotiation and multi-person conversation		
	21. Opportunity for leaners to pose their own questions		
Total Score			
Average Score			

APPENDIX G
A RUBRIC FOR SCORING THE VIDEOS FROM CLASSROOM OBSERVATIONS

A RUBRIC FOR SCORING THE VIDEOS FROM CLASSROOM OBSERVATIONS

Category	Observed Criteria	Score Given				
		0	1	2	3	4
PROBLEM SOLVING & REASONING	1. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	The students do no investigation or problem solving.	The student investigation is teacher directed.	The students utilize multiple approaches to solve the problem.	The teacher solicits multiple approaches to solve the problem.	The teacher solicits multiple approaches to solve the problem and has students present the approaches to the large group.
	2. Students used a variety of means (models, drawings, graphs, symbols, concrete materials, manipulative, etc.) to represent phenomena (quantity and time with materials).	There is no representation of the phenomenon.	The teacher represents the phenomenon.	The students represent the phenomenon.	The students represent the phenomenon in at least 2 different ways.	The students represent the phenomenon in at least 2 different ways, at least one of which is student choice.
	3. Students were encouraged to generate conjectures, (or) alternative solutions, and/or different ways of interpreting evidence.	Instructor may present interpretations, conjectures, etc., but asks students to do nothing.	At least one time, students were asked to consider an alternate solution, make a conjecture, or interpret evidence in more than one way.	The teacher accepts multiple strategies, conjectures or ways of interpreting evidence but makes not adequate effort to solicit multiple ways.	Teacher-student interactions value, encourage, and facilitate students through considers alternate solutions, and/or conjectures, and/or evidence (no explicit discussion or negotiating meaning, just idea expressing).	Whole lesson is dedicated to students discussing, exploring and critiquing/considering alternate solutions, and/or different ways of interpreting evidence, with minimal teacher guidance.
	4. Active participation of students was encouraged and valued.	Entirely instructor directed. Student participation was not encouraged and valued.	The teacher's questioning strategy involves student participation (may be opportunities for students to "shout out" ideas), but is not closely tied to concept building.	Some student questions/input is encouraged. The students describe the phenomenon but do not participate in constructing or validating the final explanation of the phenomenon (No building of explanation).	Many students engaged some time in valuable conversations that lead to class discussions but they do not play adequate role in constructing and validating the final explanation (Some building of explanation).	All students are actively engaged in meaningful conversation. The students describe the phenomenon and play a significant role in constructing and validating the final explanation of the phenomenon.

	5. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures (quality).	The students are passively engaged in the lesson.	The students are actively engaged, but the activity is not thought provoking. The activity might be just simple activities that are factually based (i.e., term recall or summarizing content) and students do not assess their procedures.	The students are actively engaged in a thought-provoking activity, but do not assess the validity of the procedure, or how it could be improved.	The teacher asks the students to reflect upon the procedure, but no ideas are shared with their group.	The teacher asks the students to reflect upon the procedure and the ideas are shared with their group.
	6. Students were reflective about their learning (what do you think, and how do you know).	There is no evidence of student reflection.	The teacher asks a question to prompt students to consider how they think about their learning, but no discussion occurs or this doesn't follow through with how this helped their connection to learning.	The teacher asks a question to prompt students to consider how they think about their learning. However, there is some discussion occurring but it is not potential interaction.	The students discuss questions such as "How do we know this? How can we be sure? What does this tell us about what we know? Do you want to change your idea? Why do you think that way?" only within their small group or large group.	The students discuss questions such as "How do we know this? How can we be sure? What does this tell us about what we know? Do you want to change your idea? Why do you think that way?" within their small and large group.
	7. Intellectual rigors, constructive criticism, and the challenging of ideas were valued (debating ideas).	The students articulate no ideas related to the activity.	The students articulate one idea, but no competing ideas are offered (perhaps by shout out to teacher's quires).	The students articulate more than one idea. There is some competing idea but it is not a critical discussion.	There is critical discussion of the ideas within the small groups and/or whole group.	There is critical discussion of the ideas within the small groups and cross-group or whole group. OR Students debate ideas through a negotiation of meaning that results in strong use of evidence/arguments to support claims.
LEARNING ENVIRONMENT	8. Students were involved in the communication of their ideas to others using a variety of means and media (variety of types and scales of delivery).	No student communication	At least one type of student-student communication (i.e., brainstorming, drawing pictures to convey ideas, mathematically).	Either more than one type of student-student communication, but not at a variety of scale (i.e., pairs, small group, group to group, whole class) or vice versa.	Multiple types of student-student interactions, at multiple scales, but not all scales are potential interactions.	Focus of the class is based on student-student interactions, which are potential through a variety of interactive scales and types (typically includes a whole class processing).
	9. The focus and direction of the lesson was often determined by ideas originating with students.	The lesson is teacher demonstration.	The student investigation or problem solving procedure is teacher directed (mathematical problem solving included).	The students generate ideas of investigation and/or problem solving procedure (mathematical problem solving included).	Students generate ideas and questions. Students have input in designing the investigation. – Or – Teacher presents problem and students design investigation.	Students generate ideas and questions. Students develop investigation throughout the process.

	10. There were a high proportion of student talk and a significant amount of it occurred between and among students (quantity of interactions).	There is no talk amongst students. Student-instructor dialog (answering question) is not scored for this item.	There is minimal student-to-student dialog.	The proportion of student-to-student talk to teacher-to-student talk is about equal.	A larger portion of the talk is student-to student; however, critical portions of the lesson are not well developed through this discourse.	This lesson is mostly student talk with critical portions of the lesson developed through student-to-student discourse.
	11. Student questions and comments often determined the focused and direction of classroom discourse (quality of student interactions).	The teacher determines the direction of the lesson with no student input.	The students discuss with the teacher, however students input only slightly influences the focus or direction of the discourse. The conversations are short and limited to "the answer", no negotiation of meaning.	The students discuss in their small groups, but the discourse is not central to the development of the description of the phenomenon. Student conversations are brief but do involve some negotiation of meaning.	The students discuss in their groups and with the teacher. This discourse is central to the development of the description of the phenomenon. Or student conversations are in depth examinations of a problem.	The students discuss in their groups, between groups, with the teacher and with the large group. This discourse is central to the development of the description and development of understanding of the phenomenon or student conversations are in depth examinations of a problem.
	12. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	The teacher makes no reference to prior knowledge.	The teacher refers to previous student experiences or relates previous learning (no respect aspect).	The teacher solicits information from students concerning prior knowledge of phenomenon.	The students write, draw, or discuss their hypothesis, estimation or prediction prior to exploration and teacher instruction.	The students write or draw a diagram or their hypothesis, estimation or prediction and discuss it in a small group or large group setting, prior to exploration and teacher instruction.
	13. There was a climate of respect for what others had to say.	No ideas beyond instructor are heard.	There is some student interaction or students' idea expressing. Teacher interaction seldom encourages student exploration and/or discussion.	Some student-student interactions provide opportunities for voicing of ideas and opinions. Teacher interactions often encourage student exploration and/or discussion.	Most student-student interactions involve talking, listening, and comfortably representing their ideas and expressing their opinions without fear of censure or ridicule. Teacher interactions usually encourage student exploration and/or discussion.	Every voice is equitably heard, respected, and valued. All students have opportunities to contribute their ideas in multiple ways without fear of ridicule. All teacher interactions encourage student exploration and/or discussion.

	14. The Lesson was designed to engage students as member of a learning community.	This lesson is completely teacher-centered, lecture only.	Lesson has limited opportunities to engage students. (e.g., some clicker, rhetorical questions with shouts out opportunities). Primarily the teacher addresses the class and some students respond.	Lesson is designed for continual interaction between teacher and students. Or there are some student-to-student interactions and discussion but little or no construction of ideas or theory building.	Lesson is designed to include both extensive teacher-student and student-student interactions. Some students in the small group contribute to the constitution of ideas and theory building.	Lesson was designed for students to negotiate meaning of content primarily through student-student interaction. All students in the small group contribute to the construction of ideas and theory building.
	15. In general the teacher was patient with the students (mostly about the time).	No opportunity to assess or teacher was not patient (no wait time, answers own questions).	There is a bit of wait time after asking a question (shout out opportunities or the first raised hand), instructor avoids answering his/her own questions. Or instructor works with student(s) to clarify their vague question.	Clear wait time (waiting for multiple student thoughts, waiting for all students have a chance to consider the question; not just taking the first raised hand or "shout out".	Providing some time for student-student interaction (still on task), but not enough time for students to explore on their own terms or not enough time for all to achieve goals.	Instructor provides adequate time for meaningful conversations to occur between students and ample opportunities for students to explore on their own terms (enough time to achieve goal).
	16. The teacher acted as a resource person, working to support and enhance student investigations.	No investigations (activity that engages students to apply content through problem solving).	Very teacher directed limited student investigation / problem solving procedure, very rote.	Primarily directed by teacher with occasional opportunities for students to guide the direction of investigation or problem solving procedure.	Students have freedom, but within confines of teacher directed boundaries.	Students are actively engaged in learning process, students determine what and how, teacher is available to help.
	17. The metaphor "teacher as listener" was very characteristic of this classroom.	Teacher was the only "talker".	At least once, teacher listed, and acknowledged or validated an idea presented.	Teacher is listening throughout (from beginning to end), but doesn't act on any ideas (but does acknowledge).	Teacher listens from beginning to end of lesson, but doesn't necessarily act on ideas throughout.	Teacher listens and acts on what students are saying from the beginning to the end of the lesson (gaining prior knowledge to assessing student understanding).
QUESTIONING	18. The teacher's questions triggered divergent modes of thinking (by students).	No divergent modes of thinking	Students listen to teacher present an example of more one answer or interpretation, but student thinking limited to individual questions about the material.	Students interact in response to teacher-framed question(s) that has/have more than one answer or interpretation, but the directions ask for just one "right" response.	The teacher asks open-ended questions and offers multiple explanations or explores connected areas to the large group or to small groups.	The teacher asks open-ended questions and offers multiple explanations or explores connected areas to the large group and to small group.

	19. Questioning to encourage student's investigation	No evidence	Teacher uses probing question that aim to process interaction or follow up students' idea or to promote students to think deeper about the problem solving procedure.	Teacher uses questioning that require students to express idea or think openly about the solution to a problem (mathematical problem included).	Teacher uses questioning to enhance students to express some of the ideas related to the investigation.	Teacher uses questioning to promote students investigation throughout inquiry process.
	20. Teacher's questioning to promote students' negotiation and multi-person conversation	No evidence	Teacher's question is aimed to hear students' short answer (perhaps shout out) or their wrong or right answer.	Teacher asks more open-ended questions to hear students' ideas or explanations but no negotiation between teacher-student and student-student.	Teacher's questions focused negotiation but on teacher–student interaction rather than to promote student-to-student discussion	By teacher's questioning (assisting), students are asked to explain and/or challenge each other's response rather than teacher passing judgments.
	21. Opportunity for leaners to pose their own questions	No opportunity for learner to pose their own question or engaged by questions from any sources.	Learners engage in questions provided by teacher, materials or other source (mathematical problem solving question is included).	Learners ask interaction question to teacher or peers when they disagree or curious. This is a clarification question (the question is not aimed for investigating just a short answer or a brief explanation). This might be in form of student-instructor dialogue (answering question).	Learner selects among the question provided by the teacher. Or based on teacher's facilitation, learners sharpen or reformulate the suggested question and pose their own new questions, tied to their investigating purpose.	Leaners have opportunity to pose/formulate their own investigating questions (researchable or testable questions).

***This rubric is modified from the Reformed Teaching Observation Protocol (RTOP), developed by the STEM Center retrieved from HTTP://MATHED.ASU.EDU/INSTRUMENTS/RTOP/INDEX.SHTML

*** Questioning session (Q.19-21) was created by taking an idea from Bloom & Krathwohl (1956); and NRC (2000).

APPENDIX H
CODEBOOK FOR ASSESSING THE SHIFT OF TEACHERS VIEWS
OF LEARNING AND THEIR TEACHING PRACTICES

CODEBOOK FOR ASSESSING THE SHIFT OF TEACHERS VIEWS OF LEARNING AND THEIR TEACHING PRACTICES

Observed Criteria	Categories	Sub-Categories	Description	Example
Problem Solving& Reasoning	Inquiry Investigation & Problem Solving Activity	-	Focus the class on inquiry investigation and problem solving. Teacher encourages students' active participation.	Teacher provides a mathematics problem in her white board. Ask students to come out to solve a problem in front of the class (FO).
	Thought-provoking activity	-	Use interesting and challenging science activities that promote students' discussion/debating and students' critiquing. Also use activities that relate concepts studies in class to contemporary society issues which can improve student achievement and attitudes toward science	I taught Newton 1^{st} law by asking them to work in-group on the variety situations I provided in that how these situations relate to the Newton law. I gave them time to think, analyze, and discuss in-group. How is the situation? Any forces act on the object? (LI).
	Reflect on learning (Meta-Cognition)	Reflect upon procedure	Opportunities for students to think about their learning and reflect their own understanding about the task/assignment/activity they are working on and the procedure how to get the answer	Most of my questions do not right to the answer that they have to get exact answer as the teacher's but rather I emphasize on the procedure that they use to get to the answer (RI).
	Reasoning	Elaborative reasoning	Students use or are encouraged to use evidence support their claim during negotiating or explaining	If they think it is wrong, they have to say how it is wrong. I want them to have reasoning. I want them to have thinking skill and think logically (LI).
Learning Environment	Promoting public communication	-	Conducting an environmental setting to promote students' public communication	Presentation, gallery walk or group work (FO).

	Establishing a Non-threatening Learning Environment	Equitability of voices	All students have a right to talk equitably.	Everyone is free to talk. Students can talk to me anything. They can also share ideas anytime (RI).
		Opportunity to contribute ideas comfortably, without fear of ridicule	Teacher treats students with respect equitably and is not embarrassing them when they response a wrong answer.	If students provide me a wrong answer or incomplete answer, I won't blame them. I mean I won't make them feel bad. I won't be disappointed with a wrong answer of my students (RI).
	Student Voice /Student Talking	-	The proportion of students' talk in a classroom.	So, if you ask about students' opportunities to talk, I can say that they always have (LI).
	Dialogical Interaction/ Classroom Discourse	Teacher-student Interaction	Providing opportunities for scientific discussion and debate between teacher and students	Students provide a wrong answer then teacher corrects him (FO).
		Student-student Interaction	Providing opportunities for scientific discussion and debate among students	Students discuss and negotiate their solution ideas in-group (FO).
	Establishing a learning environment	Collaborative Learning - Small group - Group to group - Whole group	Students' collaborative learning appears in a classroom.	Everyone in the group participate in an activity. Some draws the answer. Some throws the ideas. Some listens (FO).
		Individual Learning	Students' individual learning appears in a classroom, no discussion among students.	This is the lab class. So, students are arranged to sit in-group. I personally don't like this way. I like them to individually study while we learn physics concepts.
		Teacher shares the work with students	Teacher and students collaboratively work/share responsibility in a class's activity.	The teacher and students cooperatively think about the solution of the problem (LI).

	Waiting time	No wait time offering	No waiting time offering for students to think/talk/ or response to the questions	She gives an answer immediately right after the first student's response (FO).
		Adequate wait time offering	There is adequate waiting time offering for students to think/talk/ response to the questions or meaningful conversations to occur.	Provide time for students to work on 9 problem-solving questions (FO).
	Classroom culture	Traditional classroom culture	Overall, the class is typically driven, as traditional style such as teacher is only talker.	Lecture (she is the only talker). Let students practice by themselves. However, teacher kind of controls the investigation (FO).
		Inquiry classroom culture	Overall, the class is typically driven, as inquiry style such as students performed their own learning.	In inquiry classroom, teacher is a facilitator, supporting when students have a problem (RI).
		Teachers' Questioning Purposes	Questioning to encourage student's investigation	The teacher asks for students' idea before doing an investigation (FO).
			Questioning to trigger divergent modes of thinking	The teacher asks students to think alternative way (FO).
			Questioning to promote students' negotiation & multi-person conversation	Her questioning is spread to more than one student; by doing this, students were discussing and negotiating the ideas (FO).
			Questioning to develop critical thinking and problem solving skills	Questioning to promote students to think. But I won't tell them the answer. They must think first (RI).
			Questioning to enhance conceptual understanding	Thus, I tested them how well they can connect their knowledge to the previous one that if we want to find velocity, what else do we want to know? (LI).

	Teacher responses to question	Probing response (connect, extend) Teacher directly response to students' question or his/her own question.	Teacher uses probing questions asking or students' elaboration. Teacher suddenly responses to students' questioning or his/her own question with a direct answer.	Teacher uses follow up questions to drive the discussion (FO). Teacher didn't ask the students to explain what they thought, why and how they come up with the answer. She explains the concepts back by herself (FO).
View of Learning	View of learning	Aligned to learner-centered Aligned to teacher-centered	The way teacher explains his/her view of learning is aligned to learner-centered orientation. The way teacher explains his/her view of learning is aligned to learner-centered orientation.	Learning is knowledge construction by students themselves because it is going to be a long-term knowledge (RI). Learning is receiving or absorbing new knowledge or new content (RI).
	Role of teacher	Lecturer Mentor	Teacher views his/her role as a content delivery. Teacher views his/her role as a mentor to support students to perform their own learning.	Today I feel that I didn't ask enough questions. Most of the time is teacher-transferring information (LI). I am a guide. I am a part of learning. It is not as the teacher is a leader throughout and student is a follower. It is not that way. We corroborate. We discuss and share ideas (LI).
Difficulties/ Barriers to implement ABI	Technical Dilemma	-	The dilemma involves in this part is classroom management such as group work, challenge of new teacher and student roles, or the inadequate inservice education.	There are many factors. One of them is from the teacher that does not have enough technique to work through the reformed approach (RI).
	Political Dilemma	-	The dilemma involves in this part is the lack of school or district level leadership, parent resistance to change, lack of public support, inadequate resources, or student performance on statewide-mandated end-of-grade science tests.	Material is another important factor. Our school cannot provide a real material for my students to experience (RI).

	Cultural Dilemma	-	The dilemma involves in this part is beliefs, perceptions, and values held by teachers about teaching and learning.	Students' goal in learning is about the grade or score but teacher aims for content (RI).

Note: Sources of the data shown in the example column:

FO=Field note observation; RI = Reflection Interview; LI = Lesson Interview

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