

PROFESSIONAL DEVELOPMENT FOR PRIMARY SCIENCE TEACHING IN
THAILAND: KNOWLEDGE, ORIENTATIONS, AND PRACTICES OF
PROFESSIONAL DEVELOPERS AND PROFESSIONAL DEVELOPMENT
PARTICIPANTS

A Dissertation
presented to
the Faculty of the Graduate School
University of Missouri – Columbia

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Philosophy

by

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MAY 2007

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have examined the dissertation entitled.

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A candidate for the degree of Doctor of Philosophy.

And hereby certify that in their opinion it is worthy of acceptance.

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Dedicated to my brother, who always has faith in me.

ACKNOWLEDGEMENTS

This dissertation is a result of the support from many individuals. I first want to thank my doctoral advisor, Dr. Sandra Abell, for pushing me and challenging me to achieve more than I thought possible. Your endless support enabled me to grow as an educator and researcher. I cannot thank you enough for your support throughout my entire doctoral program. My respect and admiration for you is immense.

I extend my thanks to doctoral committee. Each of you has contributed greatly to my knowledge of education throughout my doctoral program. Your comprehensive questions gave me the foundation of knowledge needed to accomplish the dissertation work. Dr. Fran Arbaugh, I have valued your unique insights and advice, and for your genuine concern and interest in me throughout this dissertation process. Dr. Lloyd Barrow, Dr. Mark Volkmann, and Dr. Steven Keller, thank you for your kindness support, thoughtfulness, and insight throughout my study.

I also want to extend my honor and thank to all the faculty members in Science Education. Working with you through the courses, projects, and internships contributed to my knowledge in science education and research. Thank you for challenging me to a great depth. I also want to thank all of my science education colleagues for friendship and all of the laughs we shared. I extend my appreciation to Michele Lee, Tina Roberts, Pat Brown, Deanna Lankford, and Kristy Halverson. I really appreciate your generous help with editing my work. I could never forget to give special thanks to Chia-Yu Wang, my true buddy and honorable driver, for her wonderful friendship and support. You are so patient giving me a ride, listening to my complaints and sharing in my victories and

failures for four years. I value your friendships and thank you for being a wonderful friend throughout my entire doctoral program.

I offer my appreciation and thanks to the Institute for the Promotion of Teaching Science and Technology (IPST), Bangkok, Thailand for all the support, including financial support, throughout my doctoral program. Your warm thoughts and faith in me are pushing me to work hard and have strong intention to devote my knowledge, experience, and time to you.

I also want to thank all of the participants in my study: Piti, Vimon, Somsri, Sommit, Manee, Chujai, Jinda, and Wanna. Thank you for devoting time to work with me and share your insights. I value your participation. My wonderful study could not succeed without you.

I want to thank my parents, Narong and Pannipa Musikul. Your love and strength helped me persist. You taught me the value of determination and hard work. Your belief that I can do anything gave me the foundation I needed to succeed. I also want to extend my love and thanks to my beloved brother, Alongkorn, for spiritual strength. Although my brother has passed away, I would like to dedicate this achievement to him.

Last, but not least, I want to give a big thanks to my hubby Akajate, who admittedly received the brunt of my stress. Thank you for strengthening our long-distance relationship throughout phone calls, MSN conversations, or many visits when we are half of the globe apart. You gave me the encouragement, emotional support, and understanding throughout my graduate career. I value everything that you have done to help me during my doctoral program, especially your wonderful cooking.

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ABSTRACT

The purpose of this study was to examine an entire PD project as a case to understand the dynamic nature of science PD in a holistic manner.

I used a pedagogical content knowledge model by Magnusson, Krajcik, and Borko (1999) as my theoretical framework in examining the professional developers' and teacher participants' knowledge, orientation, and practice for professional development and elementary science teaching. The case study is my research tradition; I used grounded theory for data analysis. The primary data sources were interview, card sort activity, and observation field notes collected during the PD and subsequently in teacher participants' classrooms. Secondary data sources were documents and artifacts that I collected from the professional developers and teachers.

An analysis of the data led me to interpret the following findings: (a) the professional developers displayed multiple orientations. These orientations included activity-driven, didactic, discovery, and pedagogy-driven orientations. The orientations that were found among the professional developers deviated from the reformed Thai Science Education Standards; (b) the professional developers had limited PCK for PD,

which were knowledge of teachers' learning, knowledge of PD strategies, knowledge of PD curriculum, and knowledge of assessment.; (c) the professional developers' knowledge and orientations influenced their decisions in selecting PD activities and teaching approaches; (d) their orientations and PCK as well as the time factor influenced the design and implementation of the professional development; (e) the elementary teachers displayed didactic, activity-driven, and academic rigor orientations. The orientations that the teachers displayed deviated from the reformed Thai Science Education Standards; and (f) the elementary teachers exhibited limited PCK. It is evident that the limitation of one type of knowledge resulted in an ineffective use of other components of PCK.

This study demonstrates the nature of PD in the context of Thailand in a holistic view to understand knowledge, orientation, and implementation of professional developers and professional development participants. Furthermore, the findings have implications for professional development and professional developers in Thailand and include worldwide with respect to promoting sustain and intensive professional development and developing professional developers.

CHAPTER ONE: INTRODUCTION

At the time of this study, science still remains one of the most difficult subjects that elementary teachers struggle to teach. Most primary teachers believe that true knowledge exists and can be transmitted to another person through explanations and demonstrations of scientific principles. Tobin and colleagues (1990) stated that the implementation of science curricula in the elementary science classroom often emphasizes rote learning and content coverage. The report of Horizon Research (2002) on the status of elementary school science teaching demonstrated that the majority of elementary school science teachers heavily emphasized learning basic science concepts, followed only by increasing students' interest in science. Fewer than half of elementary school teachers placed a heavy emphasis on learning important terms and facts of science and learning science process/inquiry skills. The report also showed that elementary school science teachers lack content preparation, especially in the physical sciences. Relatively few science teachers in grades K–5 felt well-qualified to teach specific science disciplines. The obstacles to elementary science teaching include lack of science knowledge, insufficient facilities and equipment, and teachers' attitudes and confidence in teaching science (Abell & Roth, 1992; Appleton, 2003; Davis & Petish, 2005).

In addition to lacking subject matter knowledge in science, research indicated that the elementary science teachers also have limited pedagogical content knowledge (PCK), a special form of knowledge that is specific to teaching science. Most elementary science teachers are unaware that their students hold misconceptions of scientific concepts. Most of the elementary teachers, especially prospective and novice teachers were afraid of unexpected problems when they teach science (Zemal-Saul, Krajcik, & Blumenfeld,

2002). Thus, these teachers usually emphasize rote learning and content coverage.

Although the elementary teachers often use hands-on activities in their science classroom, many times the teachers' decision in using the hands-on activity is not to develop students' understanding of scientific concepts. Rather, they used hands-on activities to initiate the students' interest and make the classroom manageable (Appleton & Kindt, 2002).

Because of the limited knowledge in subject matter in science and limited PCK of the elementary science teachers, professional development (PD) is needed in order to address the needs of elementary science teachers. While many science PD projects are offered to elementary teachers, many PD experiences are intellectually superficial, disconnected from deep issues of curriculum and learning, fragmented, and non-cumulative (Ball & Cohen, 1999). The report of Horizon Research (2002) showed that elementary teachers believed that opportunities to learn how to teach science to special-needs students are needed in PD. However, Horizon Research reported that this area was rarely emphasized in professional development. Thus, PD that is effectively designed and implemented in response to teachers' needs is necessary.

As a science educator, one way to improve elementary science is to develop effective PD that responsive to teachers' needs. The literature on effective PD is extensive (see Chapter 2). However, implementing effective PD depends in part on the knowledge and skills of professional developers. The research literature is virtually silent on this count. Furthermore, the research says little about the entire process of PD planning, implementation, and feedback. Most studies instead focus on outcomes without

defining PD context. If we are to improve the state of PD for elementary science, we need to more deeply understand each PD context.

Understanding the PD context is even more critical when the PD under study takes place in another country. In Thailand, the Institute for the Promotion of Teaching Science and Technology (IPST) has provided PD to K-12 science teachers for many years. However, we still do not see much change in teachers' teaching or in students' learning achievement in science. The majority of Thai elementary teachers still emphasize science content coverage using traditional teaching strategies (Soydhurum, 2001). In addition, the Third International Mathematics and Science Study (TIMSS) (2005) revealed that the average performance of Thai fourth graders was below the international average and was well below that of many countries. Thus, in order to improve elementary science teaching and learning in Thailand, we need to develop a deeper understanding of the nature and process of PD.

Purpose for the Study and Research Questions

The purpose of this research is to understand the dynamics of PD design, delivery, and outcomes in Thailand by examining one PD project in a holistic manner. The research questions that guided my inquiry include:

1. What happens during the professional development workshop?
2. What are professional developers' orientations to professional development?
3. What do professional developers know about teachers, curriculum, instructional strategies, and assessment for professional development?
4. What knowledge do professional developers take into account during the professional development design process?

5. What happens during classroom teaching that takes place after professional development?
6. What are professional development participants' orientations to science teaching?
7. What do professional development participant know about students, curriculum, instructional strategies, and assessment for science teaching?

Theoretical Framework

I used the PCK model of Magnusson, Krajcik, and Borko (1999) as the theoretical framework in order to understand the professional developers' and teachers' PCK. Magnusson et al. (1999) defined PCK as teacher understanding of how to help students understand a specific subject matter. It includes knowledge of how particular topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction. They conceptualized PCK for science teaching as consisting of five components (see Figure 1): (a) orientations toward science teaching, (b) knowledge and beliefs about science curriculum, (c) knowledge and beliefs about students' understanding of specific science topics, (d) knowledge and beliefs about assessment in science, and (e) knowledge and beliefs about instructional strategies for teaching science.

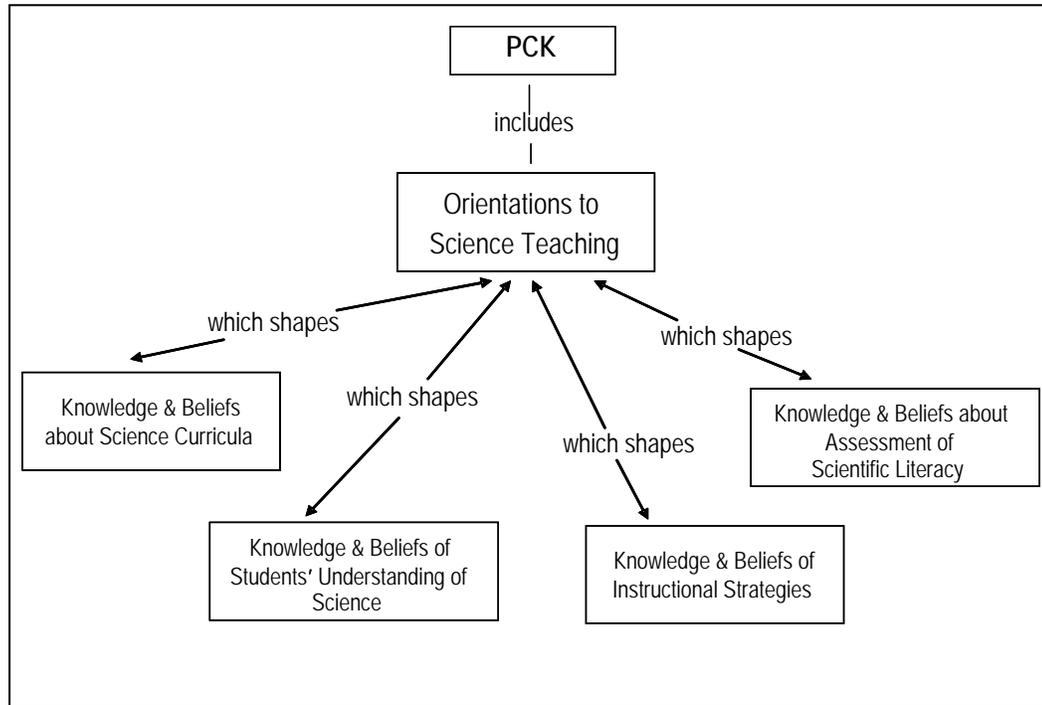


Figure 1. Components of Pedagogical Content Knowledge for Science Teaching¹.

As the researcher, I define pedagogical content knowledge in relation to science teaching as the type of knowledge that is a result of the transformation of subject matter knowledge and beliefs, pedagogical knowledge and beliefs, and knowledge and beliefs about context. With this in mind, I linked this definition of pedagogical content knowledge with Magnusson et al.’s five central components within pedagogical content knowledge for this study.

1. Orientations toward teaching science refer to teachers’ knowledge and beliefs about the purposes and goals for teaching science at a particular grade level. This component serves as a conceptual map that guides instructional decision.

¹ From Nature, Sources, and Development of Pedagogical Content Knowledge for Science Teaching (Figure 2, p. 99), by Magnusson, S., Krajcik, J., & Borko, H., 1999. In J. Gess-Newsome & N.G. Lederman (Eds.), Examining pedagogical content knowledge: the construct and its implications for science education. Kluwer: Dordrecht.

2. Knowledge of students' understanding of science refers to the knowledge teachers must have about students in order to help them develop specific scientific knowledge. Knowledge of students' understanding includes knowledge of requirements for learning and knowledge of areas of student difficulty.

3. Knowledge of science curriculum consists of two categories: knowledge of goals and objective and knowledge of specific curricular program. Knowledge of goals and objectives includes teachers' knowledge of the goals and objectives for students in the subject they are teaching. It also includes knowledge that students learned before hand and are expected to learn in the future. Knowledge of specific curricular programs consists of knowledge of the programs and materials that are relevant to teaching a particular topic of science.

4. Knowledge of instructional strategies refers to both subject-specific and topic-specific strategies. This also includes the teachers' abilities to represent a specific concept or principle in order to facilitate students' learning, as well as, knowledge of strength and weakness of particular representations.

5. Knowledge of assessment in science consists of two categories: knowledge of dimensions of science learning to assess – knowledge of the aspects of students' learning that are important to assess within a particular unit of study, and knowledge of methods of assessment – knowledge of the ways such as knowledge of specific instrument or procedure, approaches or activities that might be used to assess the specific aspects of students learning that are important to a particular unit of study.

I believe that the PCK model can also be applied to professional developers. The PCK model can be applied to my research inquiry in examining the professional

developers' knowledge, orientations, and practice in professional development and primary science teaching. In this study of professional developers' PCK, I modified Magnusson et al.'s central components of PCK to science teaching to central components that represent PCK for professional developers as follows:

(1) Orientations to PD – knowledge of the importance and goals of PD to a particular group of teachers. It also refers to knowledge of the purposes of PD for a particular group of teachers or the *overarching conceptions* of PD for a particular group;

(2) Knowledge of PD curricula – this includes professional developers' knowledge of the goals and objectives for teachers in the subject they are teaching. It also includes the knowledge professional developers have about what teachers have learned in the previous PD. This knowledge also consists of the knowledge of the general learning goals of Thai primary science curricula as well as the activities and materials to be used in meeting those goals;

(3) Knowledge of teachers' understandings of science – knowledge of teachers' requirement knowledge for teaching including their learning difficulties in particular science content. This also includes knowledge of teachers' difficulties in teaching particular science content;

(4) Knowledge of PD strategies – represents knowledge of specific strategies to help teachers comprehend specific science concepts in order to facilitate teachers' learning. This knowledge also includes knowledge of specific strategies in developing teachers' PCK. It also refers to knowledge professional developers have about strength and weakness of particular strategies; and

(5) Knowledge of assessment – includes knowledge of ways to assess teachers' learning and knowledge of aspects of teachers' learning that are important to assess within a particular unit of study.

Science Education in Thailand

Education reform in Thailand began as a result of the amendment of the constitution of the Kingdom of Thailand in 1997. The reform stipulates that all individuals have equal rights to receive education provided by the state for the duration of at least 12 years. This led to the drafting of the National Education Act of 1999 which resulted in a large-scale national education reform. A student-centered approach is at the heart of this reform. Before the reform of science education in Thailand, primary science was not taught as a separate subject but was incorporated as a part of the Life Experiences subject. Currently, science is a separate subject that every student has to learn (Soydhurum, 2001). Goals of the *Thai National Science Education Standards* (Ministry of Education [กระทรวงศึกษาธิการ], 2002) are to allow learners to participate in identification of objectives, activities, and learning methods. The students should think, do, and learn on their own as well as develop in accordance with their potential, needs, interests, and aptitude. The teachers in the reform-based curriculum are responsible for addressing both content and methods for learners, providing an atmosphere conducive to learning, and suggesting appropriate guidelines for learners with special needs.

In Thailand, both previous and current teacher preparation programs, especially the primary teachers, lack understanding of science content knowledge and also other knowledge bases for teaching (Grossman, 1990), such as pedagogical knowledge, knowledge of context, and pedagogical content knowledge. The previous and current

curricula have not emphasized developing pre-service teachers' knowledge and beliefs of teaching and learning science using inquiry or student-centered approaches. In addition, there is little or no focus on developing the teachers' abilities to selectively use strategies that maximize student learning outcomes. Although not many studies focus on teacher science literacy among Thai teachers, it is safe to say that most primary teachers do not have enough preparation in science content knowledge, pedagogical knowledge, and other knowledge bases for teaching science. Inservice and preservice primary teachers demonstrate limited science knowledge, skills, and experiences necessary in teaching science.

Because Thailand cannot rely solely on teacher preparation for implementing its education reform, professional development must be a cornerstone for the implementation of science reform. In order to help teachers meet the goals of the Thai education reform, it is necessary for the PD to: (1) help teachers move beyond the fragmented knowledge they possess to more in-depth structured knowledge; (2) establish conceptual connections within and across the concepts; (3) connect knowledge that is required for teaching for understanding; (4) provide enough experiences in the process of learning from activities that are based on integrated content and process understandings in order to increase teachers' confidence and pedagogical understanding; and (5) provide opportunities for teachers to learn science as it should be taught to students in order to help them recognize and refine their content understanding that support teaching practice (Gess-Newsome, 2001; Loucks-Horseley, Love, Stiles, Mundry, & Hewson, 2003).

The Institute for the Promotion of Teaching Science and Technology (IPST) has the mandate from the Ministry of Education to implement the subject matters of science

mathematics and technology. It sets the standards for learning at the basic level, the standards for learning at different levels and provides core subject matters for basic education. For the science strand, they consist of concept maps, contents for levels and grades, expected learning outcomes and contents of each grade, and for successive periods from grade 1 to grade 12. The IPST also provides learning units, descriptions of the basic science courses and lesson plans. All these comprise the core of basic education curriculum as stipulated in the National Education Act B.E. 2542 (Institute for the Promotion of Teaching Science and Technology, 2005).

Significance of the Study

Most researchers have studied PD design, implementation, and outcomes separately. This study is significant in that it aims to understand the dynamic of PD design, delivery, and outcomes by examining PD in a holistic manner in a specific context. The findings from this study will help researchers understand the complete picture of PD in terms of professional developers' knowledge and orientations to professional development, the role of these knowledges and orientations in PD design and delivery, PD and teacher learning, subsequent teacher practices, and the role of feedback to professional developers. In addition to this holistic account of PD, this study is significant in that I will develop PCK tools to investigate professional developers' PCK for PD. Consequently, the findings from this study will help researchers understand PCK of professional developers, a heretofore unstudied part of both the PCK and PD literature. My ultimate goal is for this research to influence future PD design and delivery in Thailand. This study will allow Thai professional developers to reflect about their orientations, practices, and PD outcomes, which will benefit to their future PD design

helping them support teachers and ultimately their students in the teaching and learning of science.

Overview of the Dissertation

This research study is divided into six chapters. Chapter One provides an overview of the study that includes rationale, purpose and research questions, the theoretical framework that guided the study, context of professional development in Thailand, and significance of the study.

Chapter Two provides the review of the literature about elementary science teaching worldwide; PCK of elementary science teachers and professional developers; and science professional development and its characteristic, strategies, and consequences.

Chapter Three provides the overarching research question and sub-questions, research tradition, context and design of the study, including role of the researcher, data collection and analysis. The end of the chapter discusses the trustworthiness of the findings as a function of the research design and tradition.

Chapter Four and Five are the findings of the study. Chapter four provides the findings about the orientations to PD, knowledge and practice of professional developers. Chapter five provides the findings about the orientations to science teaching, knowledge, and practices of elementary science teachers.

Chapter Six is a discussion of the findings in relation to the research literature, conclusion of the study, and implications and recommendations for future research.

CHAPTER TWO: LITERATURE REVIEW

This chapter is organized around three main topics that include: a) what we know about science instruction at the elementary levels, b) research on science elementary teachers' and professional developers' pedagogical content knowledge (PCK), and c) professional development (PD) models, strategies, and characteristics of effective PD. The chapter includes a description of the gaps found in the research literature that this study will help to address.

Elementary Science Teaching

The quality of elementary science teaching and learning has been a serious national concern to many countries. The US *National Science Education Standards* (NSES) were designed to serve the nation's goal to improve all students' scientific literacy (National Research Council, 1996). The standards emphasize a new way of teaching and learning science that focuses on constructivism. It also encourages changes in what and how students are taught by emphasizing inquiry as a way of achieving knowledge and understanding about the world (National Research Council, 1996). Teachers are the important factor in the success of reform-based science instruction (American Association for the Advancement of Science, 1993). A quality science teacher, as defined by the NSES, is a person who is knowledgeable in science content, curriculum, learning, teaching, and students (National Research Council, 1996). The effective science teacher is expected to have well-grounded pedagogical strategies to promote science content learning (Davis & Petish, 2005). However, for many teachers, especially elementary teachers with a limited background in science, current reform in science education requires more than just change in classroom practice. Science

Education reform also requires a different way of thinking about science, including teaching and the learning of science (Levitt, 2001). Lederman, Lederman, and Bell (2004) indicated that there is a fairly strong agreement among scientists, educators, and politicians that the primary goal of science education is to produce a scientifically literate citizenry. However, beginning and experienced teachers indicate the primary purposes of elementary science education are (1) developing logical and critical thinking, (2) developing problem-solving skills, (3) developing analytical reasoning, (4) helping to explain the world, and (5) creating relevance of science to students' daily lives (Lederman, Lederman, & Bell, 2004).

Elementary Science Teaching Worldwide

Due to the structure of elementary schools, most elementary teachers have to teach not only science, but other subjects such as language, arts, mathematics, and social science. Furthermore, in terms of the subject of science, elementary teachers also have the intimidating task of teaching all areas of science which include life, physical, and earth science (Davis & Petish, 2005). Tilgner (1990) indicated that over half of elementary teachers rank science fourth or fifth out of five subjects in terms of times that they spent to teach this subject. Twenty-five percent indicated they did not spend time teaching science at all, while the other 75 % spent less than two hours a week on science teaching (Tilgner, 1990). Mulholland and Wallace (2003) conducted a study with two preservice elementary teachers and found that the beginning teachers find teaching science more difficult than teaching other subjects. They required a variety of new skills, and different and specialized knowledge in order to teach science.

In addition to the United States, research on elementary science teaching has been studied in many countries. For example, primary science teaching in Finland focuses more on biology and geography, reflecting Finnish concern with the environment and the effects of pollution from their Baltic neighbors (Johnston & Ahtee, 2006). Science teaching and learning in the Finnish classroom focuses on attitudes and methods, but is less tightly organized around science content knowledge. Also, Finnish primary teachers see science as a difficult subject, which they do not have confidence to teach. According to a study by Johnston and Ahtee (2006), primary school teachers in England tend to have more positive attitude toward science than the Finnish teachers. Primary science education in England focuses on biology, physics, and chemistry. In Australia, Symington (as cited in Appleton, 2003) states when science is taught, the teachers tend to use teaching strategies such as teacher discussions, teacher explanation, viewing science television shows, library research, and teacher demonstrations (Appleton, 2003). The absence of self-confidence in teaching science tends to guide these elementary teachers to use teaching strategies that allow them to maintain control of the classroom knowledge flow, which often does not include appropriate ways of engaging students in science (as cited in Appleton, 2003). This claim is also supported by a study by Mulholland and Wallace (2005). They conducted a study of an elementary teacher in Australia and found that the teacher's desired her classroom to be under control and was embarrassed in front of the children if she did not have science content knowledge. Having control over the classroom helped the teacher to feel confident about what the students were learning. When teachers have limited science content knowledge and confidence in teaching

science, they either avoid teaching science or adopt teaching strategies from other subjects such as book research or writing reports to science teaching (Appleton, 2003).

Teaching and learning science in primary classrooms often focus on content knowledge as determined by the teachers' use of closed questioning methods, a method that provides less opportunities for interaction with students (Appleton, 2003). The elementary teachers' and students' perception of science teaching and learning are still far from the constructivism (Tobin, Briscoe, & Holman, 1990). Tobin et al. (1990) indicated that most of the primary science teachers hold the transmissionist view expressed in their belief that true knowledge exists and can be transmitted to another person by through clear explanations and demonstration of scientific principles. Tobin and colleagues (1990) stated that the implementation of science curricula often emphasizes rote learning and content coverage.

Two research programs were conducted with the prospective elementary teachers in three higher educational institutes: Corpus Christi State University, Purdue University, and St. Bonaventure University, to ascertain the status of elementary science teaching during the 1971-72 (Fulton, Gates, & Krockover, 1973), 1978-79 (Fulton, Gates, & Krockover, 1980), and 1985-86 (Gates, Krockover, & Wiedermann, 1987) during the school years. An assessment was administered immediately following the student teaching experience by asking prospective elementary teachers to complete a science methods student teaching questionnaire. Fulton and colleagues (1980) compared the data they collected in 1971-72 and 1985-86. They stated that the results of both studies closely paralleled each other-- the greatest liabilities of the teachers in teaching science were time, materials, and student characteristics in science classrooms. Compared to 1971-72,

Fulton, et al found that teaching science by inquiry dropped dramatically in 1985-86. The teachers devoted less time to teaching science than in the 1971-72 study. Gates and his colleagues (1987) conducted a similar study based on the former two studies of Fulton and colleagues. They found few science education increases during the 14 years of study.

They asserted:

1. The number of student teachers teaching in grades 4 through 6 has remained constant.
2. Available materials and the children continued to be the greatest assets perceived by the preservice teachers.
3. The perception of not enough time continued to be the greatest liability for science instruction in the elementary school.
4. Student teachers continued to use a skill approach for the teaching of science in the elementary school.
5. In 1971-72, only 27.7 percent of the student teachers were using either SAPA, ESS, or SCIS. The 1978-79 study indicated a figure of 80 percent. The 1985-86 figure dropped to 47 percent.
6. When compared to the 1978-79 study, more science was taught per week with a 12 percent increase for three days per week and an 8 percent increase for five days per week.
7. The percentage of student teachers who did not teach science dropped more than 50 percent over 14 years (from 19 percent to 8 percent). (Gates, Krockover, & Wiedermann, 1987, p. 641)

However, they were also concerned that:

1. Preservice teachers teaching science by inquiry dropped dramatically.
2. The amount of time devoted to teaching science dropped over the 14 years with 10 percent more teachers teaching science after 1:30 p.m.
3. The elementary science methods course was not perceived by student teachers as their greatest asset.

4. Thirteen percent fewer classrooms were teaching science in 1985-86 compared to the 1978-79, and 25 percent fewer when compared to the 1971-72 study.
5. Time continued to be the number one excuse for not teaching science in the elementary school and this concern rose from 27.7 percent in 1971-72 to 59.6 percent in 1978-79 to 62 percent in 1985-86. (Gates, Krockover, & Wiedermann, 1987, p. 641)

Research also indicates that inadequate teacher background in science (Abell & Roth, 1992; Davis & Petish, 2005; Gabel, Samuel, & Hunn, 1987; Ginns & Watters, 1995; Haidar, 1997; Meyer, Tabachnick, Hewson, Lemberger, & Park, 1998; Palmer, 2001); insufficient facilities and equipment (Abell & Roth, 1992; Appleton, 2003); attitudes, and lacking of confidence in teaching science (Appleton, 2003; Appleton, 2002) of the elementary science teachers are obstacles to effective science teaching (Bryan, 2003; Levitt, 2001; Palmer, 2001). Many elementary school teachers hesitate to teach science. Abd-El-Khalick and colleagues (1997) indicated that most of the teachers held naïve views of the nature of science and showed inadequate knowledge of the structure, function, and development of their disciplines. The teachers believed that scientists follow a recipe, called the scientific method, to conduct their investigations. Thus, the teachers overlooked the role of creativity and imagination in science.

Teachers' attitude toward science and science teaching is a barrier to good science teaching (Johnston & Ahtee, 2006). The researchers indicated that many elementary teachers have a negative attitude, which appears to have risen from their past experiences in science as a learner (Abell & Cennamo, 2004), particularly at the secondary level (Mulholland & Wallace, 1996; Skamp & Mueller, 2001). The researchers claimed that many elementary teachers have experienced years of passive, lecture-driven science when they were students. Thus, many of them develop a vision of themselves as science

teachers that is in reaction to their experience as science learners (Abell & Cennamo, 2004; Bryan, 2003).

Many elementary teachers have limited science matter subject knowledge (Anderson & Mitchener, 1994) and many of them are deficient in science content (Appleton, 2005). The studies indicated that the majority of elementary science teachers exhibit perceptual understanding rather than conceptual understanding of these concepts, especially at the particulate level (Gabel, Samuel, & Hunn, 1987; Ginns & Watters, 1995). The teachers have fragmented understanding and have difficulties to relate the observable macroscopic changes to the invisible molecular events (Gabel, Samuel, & Hunn, 1987; Haidar, 1997; Valanides, 2000). Furthermore, many preservice elementary teachers are not reasoning at a level required to visualize and construct the mental models needed to solve respective problems (Ginns & Watters, 1995). For example, the research on teachers' knowledge of chemistry concepts about nature of matter showed that the limited teachers' knowledge in the content is a critical obstacle for teachers in order to be able to represent their knowledge appropriately and in multiple ways (Davis & Petish, 2005). Moreover, the prior studies revealed that the teachers often have conceptions about chemistry topics similar to those of their students (Calik & Ayas, 2005; Haidar, 1997). Valanides (2000) indicated that when teachers were less knowledgeable in their content, they were more likely to rely upon low-level questions and to give their students less opportunities to speak.

Many researchers reported that experienced teachers adopt a reform-based curriculum superficially, then continue to teach in traditional ways (Keys & Kennedy, 1999; Olson, 1981; Welch, Klopfer, Aikenhead, & Robinson, 1981). For instance,

Tilgner (1990) conducted a study on elementary teachers to investigate their perceived role in elementary science. She found that the elementary teachers see themselves primarily as dispensers of facts. They also avoid teaching topics in science that they might be asked about by their students. The teachers indicated that they feel that they may not, but should, have all the right answers for the students when they ask a question in science. When the teachers lack experience and understanding, they feel less certain of their knowledge and rely more on the textbook to provide the knowledge they think they are to dispense.

Many researchers conducted studies with elementary teachers about their science teaching and studies about ways to increase the quality of science teaching in elementary classrooms for many decades. We find little change in science teaching at elementary grades. Horizon Research (2002) reported the status of elementary science teaching in the current century. This report describes the status of elementary (grades K–5) school science instruction based on the responses of 655 science teachers, 320 grade K–2 teachers and 335 grade 3–5 teachers. The report asserted:

- Less than one-third of elementary teachers reported feeling very well qualified to teach each of the science disciplines. More grade K–5 teachers stated feeling very well qualified to teach life science and earth science than physical science, which is consistent with teacher reports of their college coursework.
- Grade K–5 self-contained classes spent an average of 25 minutes each day in science instruction, compared to 114 minutes on reading/language arts, 53 minutes in mathematics, and 23 minutes in social studies. This comparison

has been done only with teachers who teach all four of these subjects to one class of students were included in the analyses.

- Grade 3-5 teachers used discussion and lecture strategies in teaching science more often than Grade K-2 teachers. Teachers reported their students listening and taking notes during a presentation by the teacher at least once a week in their classes.
- Grade 3-5 teachers allowed students to work in groups at least once a week. The small group working usually takes place in labs and/or hands-on work.
- In half of the elementary school science classes, teachers report students doing hands-on/laboratory science activities or investigations at least weekly, with students much more likely to be following specific instructions in completing an activity or investigation than designing or implementing their own investigations. In addition, grade K-2 students had more opportunities to work on hands-on/laboratory activities in the most recent lesson than students in grade 3-5.

In addition, the Horizon research also reported that elementary teachers were lacking in content preparation, especially in the physical sciences. Most elementary teachers believed that they were not well qualified to teach specific science topics. In contrast, they believed that they were well prepared to implement more general pedagogical practices, such as listening and asking questions of their students and engaging their students in hands-on work and cooperative groups. However, these teachers did not feel they were qualified to teach science as aligned with the science standards, which emphasize developing students' conceptual understanding of science,

making connections between science and other disciplines, and leading students using investigative strategies.

Research also indicates that teachers' instructional decision-making is directly influenced by their personal knowledge and beliefs (Putnam & Borko, 2000). In particular, the knowledge base of expert teachers is comprised of rich teaching experiences, which influence the decision-making practices in their classrooms (Avraamidou & Zembal-Saul, 2005; Mulholland & Wallace, 2005; Munby, Russell, & Martin, 2001). Abell and colleague (1992) illustrated three factors that relate to each other and influence elementary teachers' teaching of science. These factors were classroom practice, perceived constraints, and beliefs about science teaching and learning. Levitt (2001) indicated the beliefs teachers hold about teaching and learning, including beliefs about their students, have a significant influence on teachers' behavior. In addition to the poor science content knowledge of the elementary teachers, science is often a subject in the elementary level that the teachers seem reluctant to teach because of a negative attitude toward science (Abell & Roth, 1992; Akerson, 2004; Mulholland & Wallace, 1996). The attitude of elementary teachers towards teaching science affects the way in which they present science in the classroom and, accordingly, their attitudes impact student perception and interest in the subject (Kelly, 2000). Researchers also found that if the teachers did not like science, their student tended not to like science (Shrigley, 1974). Hence, confidence and background go hand-in-hand (Mulholland & Wallace, 1996). Bandura (1986) theorized that behavior is linked closely with beliefs and self-efficacy. Thus, teachers' behavior in classroom teaching reflects their confidence in their teaching abilities (Ramey-Gassert & Shroyer, 1992).

Furthermore, the experienced elementary teachers feel the factors of time, facilities, and equipment are a barrier to science teaching (Abell & Roth, 1992; Cronin-Jones, 1991; Levitt, 2001). The elementary teachers may be convinced of the value of hands-on activities and the use of cooperative learning, but often are not able to help students develop science content understanding from the activity (Appleton, 2002;, 2003; Tobin, Briscoe, & Holman, 1990). Rather, many of them see the role of hands-on activity as increasing students' interest and enthusiasm (Levitt, 2001). Some elementary teachers use hands-on activities in science classroom because they keep the students busy (Appleton & Kindt, 2002; Mulholland & Wallace, 2003).

Appleton (Appleton, 2002; Appleton & Kindt, 2002) studied beginning elementary teachers cope with teaching science. The results of the studies reveal that the beginning teachers cope with their limited science content knowledge and limited science PCK using two strategies: science avoidance and a heavy reliance on activities that work. As opposed to the novice teachers, the experienced elementary teachers heavily relied on their teaching science on activities that work instead of avoiding the teaching of science. Appleton's (2002) explanation of the characteristics of the activities that work is summarized in Table 1.

Table 1

*Summary of the Characteristics of Activities that Work**

Characteristic	Description
<ul style="list-style-type: none"> • Activities that work are hands-on (Appleton, 2002, p. 398). 	<ul style="list-style-type: none"> • Safe hands-on activities that have predictable outcomes, and draw from the teachers' own experience or those of trusted colleagues (Appleton & Kindt, 2002, p. 49).
<ul style="list-style-type: none"> • Activities that work are interesting and motivating for the children (Appleton, 2002, p. 399). 	<ul style="list-style-type: none"> • Activities that would take the students' attention (Appleton, 2002, p. 399).
<ul style="list-style-type: none"> • Activities that work are manageable in the classroom (Appleton, 2002, p. 400). 	<ul style="list-style-type: none"> • Activities that the teachers could implement but still maintain class control (Appleton & Kindt, 2002, p. 49).
<ul style="list-style-type: none"> • Activities that work have a clear outcome or result (Appleton, 2002, p. 402). 	<ul style="list-style-type: none"> • Activities in which the teachers believe that nothing unexpected would happen during the activities which would confuse them or the students (Appleton & Kindt, 2002, p. 49).
<ul style="list-style-type: none"> • Activities that work draw on equipment that is really available (Appleton, 2002, p. 403). 	<ul style="list-style-type: none"> • Activities for which the teachers have materials readily at hand (Appleton & Kindt, 2002, p. 53).
<ul style="list-style-type: none"> • Activities that work lend themselves to integration (Appleton, 2002, p. 403). 	<ul style="list-style-type: none"> • Activities that fit into the integrated curriculum using themes, which are common in the elementary level (Appleton, 2002, p. 403).

* Developed from the findings described in Appleton (2002) and Appleton & Kindt (2002).

Elementary Science Teaching in Thailand

In Thailand, most primary teachers are not science majors and many of them do not enjoy teaching science (Soydhurum, 2001). Also, most elementary teachers are not accredited in science (Office of the National Education Commission, 2001). Only 7.7 percent of the primary school teachers had earned degrees in science (Office of the National Education Commission, 2004). Many elementary school teachers believe that

everybody can teach science at the primary level and the teachers do not need to deeply understand science to teach in these levels (Soydhurum, 2001).

At the elementary level, science has been separated from Life Experience subject to become a single subject encompassing life, physical, and earth science. The current science curriculum in Thailand is designed so that students learn some science concepts by exploration and experimentation. A study on views of Thai elementary teachers and professional developers regarding good science teaching (Musikul & Abell, 2006, January) revealed that Thai elementary teachers believe that being able to apply scientific skills is the primary goal of teaching science in the primary levels, rather than developing conceptual understanding of phenomena. Although the teachers believe that they should change their role in teaching science from knowledge-driven toward activity-driven, and from teacher-centered toward student-centered, they still see themselves as dispensers of facts. The teachers indicated that student ability, time and limited material, and nature of testing were important factors that constrain science teaching.

Summary

The review of literature about the elementary science teaching reveals that there have been few changes in science teaching practice over the past decades. Although there are actions to help the teachers to change the way they teach from traditional approach to more constructivist approach, the general science teaching approach is still far away from inquiry. The teachers are still hesitant to teach science. When science is taught, the teachers frequently use other types of teaching strategies that are appropriate for teaching other subjects, but not in teaching science. In recent years, hands-on activities have been frequently used in science lesson than in previous years. However, the purpose in using

hands-on activities with students depends on the teachers' perceptions and goals in elementary science education. The obstacles and anxiety in teaching science occur from the lacking of science content knowledge background, self-efficacy in teaching science, and positive attitude toward science teaching and learning. Furthermore, elementary teachers feel science teaching is constrained by time restrictions in the classroom, facilities, equipment, and support from the school and their colleagues.

Pedagogical Content Knowledge

Shulman (1986) first coined the term pedagogical content knowledge (PCK) to describe the special type of content knowledge that goes beyond knowledge of subject matter to the dimension of subject matter knowledge for teaching. He explained that,

Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, example, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others (p. 203).

Shulman (1987) described seven types of teacher knowledge: content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners, knowledge of educational contexts, and knowledge of educational aims, purposes, and values. According to Shulman, knowledge for teaching is not simply one's own understanding of a conceptual area but the adaptation of this understanding so that it can be represented to others and the difficulties that others may have in developing their own understanding are appreciated.

In later years, Grossman (1990) proposed the four central components of PCK. The first component includes knowledge and beliefs about the purposes for teaching a subject at different grade levels. The second component includes knowledge of students'

understanding, conceptions, and misconceptions of particular topics in a subject matter. The third component is curricular knowledge, which includes knowledge of curriculum materials available for teaching particular subject matter, as well as knowledge about both horizontal and vertical curricula for a subject. The final component of PCK includes knowledge of instructional strategies and representations for teaching particular topics.

In 1999, Magnusson, Krajcik, and Broko proposed that PCK is a domain which links content with pedagogy. Specifically, it takes four forms: conceptions of purposes for teaching subject matter (orientations); knowledge of student understandings, conceptions, and misconceptions of particular topics in a subject matter; curricular knowledge; and knowledge of instructional strategies and representations for teaching particular topics. Magnusson, Krajcik, and, Broko (1999) present a model of the relationship among the domains of teacher knowledge: subject matter knowledge, pedagogical knowledge, knowledge about context, and PCK, which is influenced PCK by the first three domains.

Thus, PCK is a special form of knowledge that bundles subject matter knowledge with knowledge of learners, learning, and pedagogy. These bundles offer a crucial resource for teaching such as helping teachers anticipate what students might have trouble learning, and showing alternative models or explanations to mediate those difficulties. The ability to transform subject matter knowledge requires more than knowledge of the substance and syntax of the discipline. It also requires knowledge of learners and learning, of curriculum and context, of aims and objective, and of pedagogy. Drawing upon these knowledge and skills, teachers are able to translate their knowledge of subject matter into instructional representations (Grossman, Wilson, & Shulman,

1989). In addition, PCK is developed by an iterative process that is rooted in classroom practice, implying that prospective and novice teachers usually have little or no PCK at their disposal (De Jong, Veal, & Van Driel, 2002).

Elementary Science Teachers' PCK for Science Teaching

Wilson et al. (1987) indicated that successful teachers cannot simply have an intuitive or personal understanding of a particular concept, principle, or theory. Rather, in order to foster understanding in their students, the teachers must themselves understand ways of representing the concept for the students. They must have knowledge of the ways of transforming the content for the purposes of teaching. Thus, teachers should learn science and be prepared in ways that are different from future scientists or other careers. They must have a knowledge of the subject matter that includes a personal understanding of the content as well as knowledge of ways to communicate that understanding in order to foster the development of subject matter knowledge in the minds of students (Grossman, Wilson, & Shulman, 1989, p. 10). However, research indicates that teachers, especially elementary teachers, have a perception rather than a conceptual understanding of scientific ideas. The science knowledge that teachers have is fragmented and lacking a connection to other topics within and among other areas in science (Calik & Ayas, 2005; Gabel, Samuel, & Hunn, 1987; Ginns & Watters, 1995; Haidar, 1997; Valanides, 2000; Wallace & Loudon, 1992). In addition, many elementary teachers also hold alternative conceptions about the science content they are suppose to teach (Abd-El-Khalick & BouJaoude, 1997). These alternative conception are often similar to those held by the elementary students (Calik & Ayas, 2005; Haidar, 1997).

Studies on elementary teachers' PCK in teaching particular science topics are rare. However, there is evidence that although subject matter knowledge is very important for teachers, having subject matter knowledge alone does not guarantee that it will become transformed into representations that will help students comprehend targeted concepts. According to PCK model of Magnusson et al. (1999), PCK for science teaching consists of five knowledge components including 1) orientations for teaching science 2) knowledge of students, 3) knowledge of teaching strategies, 4) knowledge of science curriculum, and 5) knowledge of assessment methods.

With regards to knowledge of students' learning, Zembal-Sual, Blumenfeld, and Krajcik (2000) conducted a study with two prospective elementary teachers. The study revealed that although the two prospective teachers maintained their emphasis on planning multiple representations of content that was scientifically accurate, they were generally unable to assist the students in identifying and interpreting the relevant concepts. When unexpected dilemma occurred while the students were doing the activity, the prospective teachers abandoned the representation. Instead, they told the students that the task was too difficult to continue. Zembal-Sual et al. suggested that although prospective teachers and beginning teachers might have good background knowledge, they might not be able to maintain the subject matter emphasis if they did not have opportunities to develop understanding about students' learning, such as their prior knowledge, learning difficulties, and common misconception for learning a particular concept. Abd-El-Khalick & BouJaoude (1997) indicated that many teachers believed that the students' misconceptions should be rare because they were being introduced to such concepts for the first time. Many teachers were unaware that students have prior

knowledge before they receive any formal science instruction, and that a misconception often persists and survives beyond formal science teaching (Abd-El-Khalick & BouJaoude, 1997).

With regards to knowledge of science teaching strategies, elementary teachers, especially prospective and novice teachers, have difficulties in knowing what questions they might ask the students and when is the appropriate time to ask, give advice, and give accurate answer. A study conducted by Hayes (2002) revealed that prospective teachers were concerned that an inquiry approach required that the teacher should not give students answers to their questions. The teachers realized that they could give the students some answers to encourage them to continue their investigation as well as a way to eliminate their frustration. However, teachers were still not sure when would it was appropriate to provide some answers to students. The novice teachers do not know how to modify or use other activity or strategy that would help the students understand a particular concept. According to Magnusson et al. (1999), knowledge of teaching strategies also include knowledge about topic-specific activities in which teachers know how the particular activity could help students to understand specific concepts. However, research on elementary science teaching revealed that the elementary science teachers have poor understanding on the activities that they provided to students. Much research by Appleton and colleagues showed that elementary teachers adopt the hands-on activities in their science teaching (Appleton, 1999; Appleton, 2003; Appleton, 2005; Appleton & Kindt, 2002). Many times the teachers' decision in using the hands-on activity in the classroom is not intended to develop the students' understanding of scientific concepts.

Research on elementary teachers' PCK in teaching particular science topics is limited. In addition, most of the research focused on prospective and novice elementary teachers, but few studied experienced elementary teachers. There are several studies about the PCK of secondary science teachers. For instance, De Jong, Veal, and Van Driel (2002) reviewed the chemistry teachers' PCK in teaching stoichiometric calculations.

The result of this study can be summarized as follows:

1. Chemistry teachers with insufficient topic-specific PCK may, at times, provide inappropriate chemical topic demonstrations that could reinforce student misunderstandings. This problem is most likely to occur among teachers who have out-of-field teaching assignments.
2. Excellent SMK, knowledge of how students learn, and knowledge of alternative representations are prerequisites for the selection and use of appropriate and effective analogical explanations.
3. Chemistry teachers' choice of a strategy for teaching is often not very adequate from the perspective of student learning. Their teaching strategies are often influenced by their preferred conception of the mole. (De Jong, Veal, & Van Driel, 2002)

Elementary science teachers are hesitant in teaching science (Abell & Roth, 1992). Compared to secondary school teachers, elementary teachers do not have adequate science content knowledge (Abd-El-Khalick & BouJaoude, 1997; Abell & Roth, 1992), self-efficacy in teaching science, and positive attitude to science teaching and learning of the elementary teachers (Appleton, 2002; 2003). Furthermore, elementary teachers feel their science teaching is constrained by the time restriction in the classroom, still facilities, equipment, and supports from school and colleagues. Thus, it could be safely assumed that the elementary teachers should have limited PCK to science teaching specific topics similar to the secondary teachers that De Jong and colleagues summarized in their study.

Professional Developers' PCK

A significant amount of research has been done on the PCK for the elementary science teaching (Appleton, 2005; Avraamidou & Zembal-Saul, 2005; Mulholland & Wallace, 2003; 2005; Zembal-Saul, Blumenfeld, & Krajcik, 2000; Zembal-Saul, Krajcik, & Blumenfeld, 2002; Zembal-Saul, Starr, & Krajcik, 2001), but little research has examined PCK from the perspective of the science teacher educator. One study, conducted by Smith (2000), investigated an elementary science teacher educator's PCK in her science methods class. Smith indicated that the educators of elementary science teachers have a role in helping future teachers construct knowledge for elementary science teaching. These educators should have knowledge about (1) the conceptions of science as science learners that preservice teachers bring to the science method courses, (2) strategies for teaching preservice teachers, (3) curriculum materials and activities that are effective in helping preservice teachers construct knowledge of students' naive ideas, (4) representations that would help the preservice teachers learn and facilitate their growth as elementary science teachers. Smith found that the preservice teachers attended the science method class with limited science content knowledge. Smith also found that the teacher education students usually followed activity directions to produce results when they did experiments. The preservice teachers indicated that in regards to the study of science, it required a lot of memorizing of definitions, lectures, and tests which lead to anxiety and possible failure. The findings about the teacher educators' and the students' PCK helped Smith to redesign and plan her course in order to reduce students' anxiety and better understand what science actually is. Smith indicated that knowledge helped her

to recognize the underlying assumptions that were common in students and increased her patience and persistence in working with preservice teachers.

As science teacher educators, professional developers play a role in helping in-service elementary teachers to construct knowledge for elementary science teaching. However, I could find no published research, at the time of this study, has been done on the professional developer's PCK.

Summary

We know that elementary teachers lack subject matter knowledge (Abell, 2007). However, the literature on elementary teachers' PCK is less robust. The review of the literature about the elementary science teachers' PCK reveals that the PCK of most of the elementary teachers is still limited. In addition to the subject matter knowledge in science topics, the knowledge base that composes much of PCK, including knowledge about learners, knowledge about teaching strategies, knowledge about science curriculum, and knowledge about assessment for specific topics. Furthermore, research about the professional developers' PCK to PD is non-existent. Thus, more research on elementary teachers' and professional developers' PCK is needed.

Professional Development

Model of Professional Development

Guskey and Sparks (cited in Guskey, 2000) developed a model delineating the major components in the relationship between PD and improvements in student learning (see Figure 2). This model reveals that the quality of PD is influenced by a variety of factors. The arrows in the model represent the direction of those effects. The influence of PD on student learning is accomplished principally through its direct effect on teacher

knowledge and practice and is a primary factor influencing the relationship between PD and improvement of student learning (Guskey, 2000). Administrator’s knowledge and practice about science teaching indirectly, but importantly, influences the improvement of student learning in terms of forming school policies, and supporting and supervising teachers. According to Guskey (2000), all the factors and components identified in the model strongly affect the relationship between PD and the improvement in student learning.

According to the Guskey and Sparks PD model (Guskey, 2000), three factors influence the quality PD. Those factors are (a) content characteristics, (b) process variables, and (c) context characteristics. All three factors are important in determining the quality of PD.

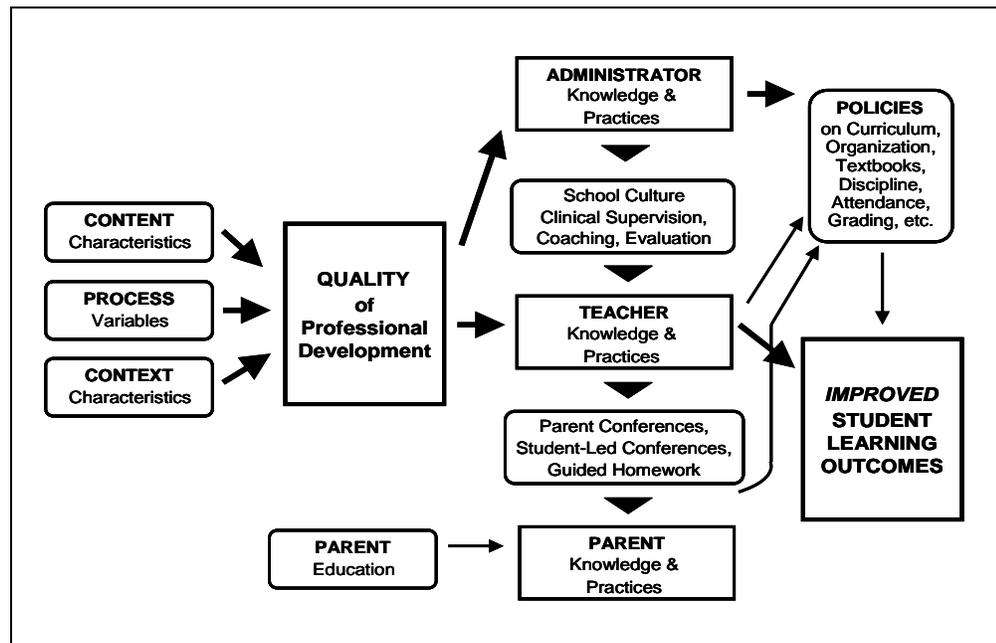


Figure2. Model of Relationship between Professional Development and Improvement in Student Learning.²

² From Guskey, T. R. (Figure 3.2, p. 73, 2000). *Evaluating professional development*. Thousand Oaks, CA: Corwin Press.

The content characteristics refer to the “what of professional development” (Guskey, 2000, p. 73). including the goals and the concerns of the particular PD. Content characteristics also include to the aspects relating to the magnitude, scope, credibility, and practicality of the change required to implement the new knowledge and skill. The process variables refer to the “how of PD” (p. 74). This means the type and forms of PD. It also means how the PD activities are planned, organized, implemented, and followed-up. Context characteristics refer to the “who, when, where, and why of PD” (p. 74), which involve the organization, system, or culture in which the PD takes place and where the new understanding will be implemented. Guskey (2000) indicated that teaching and learning were complex endeavors. Thus, PD must be shaped and integrated in ways that best suit regional, organizational, and individual context, such as the local values, norms, policies, structures, resources, and procedure.

The Guskey model also shows that the influences of PD on improvements in students’ learning are accomplished through its direct effect on teacher and administrator knowledge and practices. The bold arrow between teacher knowledge and practices and improvement of students’ learning means knowledge and practices of teachers are primary factors influencing the relationship of PD and students’ learning. If the PD is not able to develop teachers’ conceptual understanding or change the classroom practices they employ, little improvement in students’ learning can be expected.

The model illustrates that administrator also influence improvement of students’ learning, but indirectly. The influences can occur in two ways, including (a) to form school policies regarding school organization, curriculum, assessment, and textbooks; and (b) to interact with teachers through the clinical supervision, coaching, and formative

evaluation. Deal and Peterson (as cited in Guskey, 2000) indicated that the administrator can also develop a learning community within a school.

In order to measure the quality of PD, Guskey (2000) identified five critical levels of PD evaluation. These levels are ranked from simple to more complexes, with each level building on the one before. These levels include:

(1) Participants' reactions: focus on measuring teachers' satisfaction of the PD.

The information is generally gathered through questionnaires hand out at the end of PD,

(2) Participants' learning: focus on measuring teachers' knowledge, skills, or attitudes. The assessment methods are dependent on the goals of PD,

(3) Organizational support and change: focus on measuring how school policies support teachers' teaching and change,

(4) Participants' use of new knowledge and skills: focus on measuring did what teachers learn make differences in their professional practices, and

(5) Student leaning outcomes: focus on measuring did the PD benefit students' learning achievement and performance.

A few years later, Loucks-Horsley, Love, Stiles, Mundry, and Hewson (2003) created a professional development design framework for science and mathematics education in light of knowledge gained from research and practice in PD. The model captures a "process of decision-making" (Loucks-Horsley et al., 2003, p.3) informed by relevant inputs (see Figure 3) during the planning process.

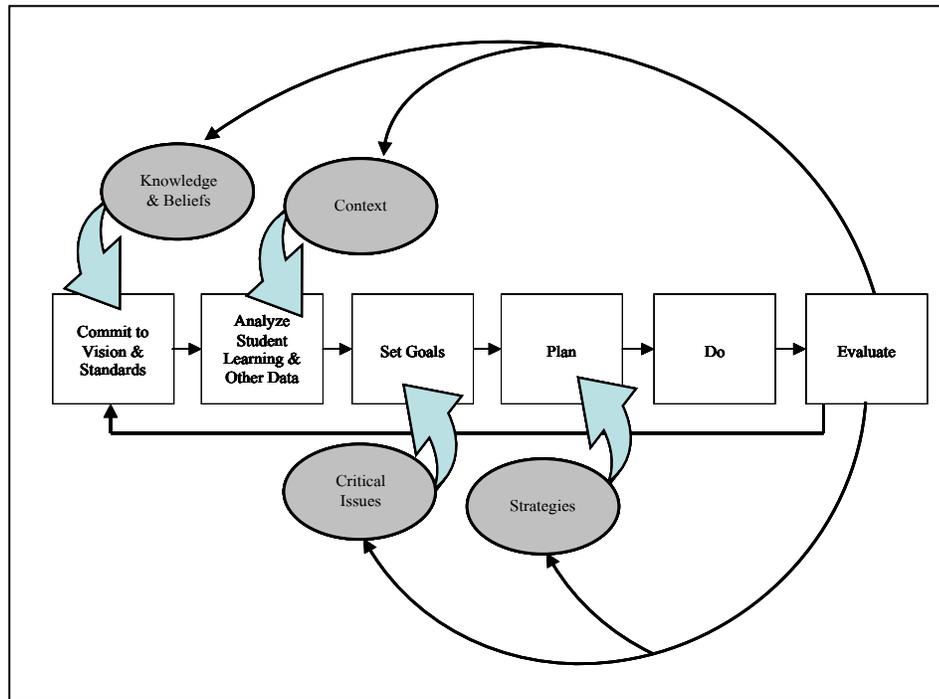


Figure 3. Design Framework for Professional Development in Science and Mathematics³.

According to the model, the rectangles connected with horizontal arrows represent a set of sequenced generic planning and implementation on, incorporating the following actions: commit to vision and standards, analyze student learning and other data, set goals, plan, do, and evaluate. The four ovals above and below the planning implementation sequence represent important inputs to the design process that assist professional developers to make informed decisions. The four inputs are categorized as: knowledge base and beliefs, understanding of aspects unique to the context, critical issues common to science and mathematics reformers across contexts, and a range of PD strategies. Arrows from the inputs to the planning sequence boxes indicate when these inputs are most important to start to consider in the planning sequence. The model

³ From Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry, S., & Hewson, P. W. (Figure 1.2, p. 4, 2003). *Designing professional development for teachers of science and mathematics* (2nd ed.): Thousand Oaks, CA: Corwin Press.

assumes that once an input begins to inform the planning sequence at a given phase, it will continue to do so for the remainder of the phases. The evaluation phase serves as feedback to inform the vision and goals of the PD. Evaluation also links back to and potentially impacts all four inputs as well as the developer's commitment to a reform-minded vision and standards.

The design framework provides a map for professional developers to achieve the desired goals for students and teachers. Professional developers' knowledge and beliefs play a role in the first designing phase: commit to vision and standard. Five distinct but related knowledge bases that inform the works of professional developers are knowledge and beliefs about learner and learning, teacher and teaching, nature of science and mathematics, professional development, and change process. Understanding of context is the second input mentioned by Loucks-Horsley et al (2003). In general, professional developers consider context in the second phase of the planning sequence. Loucks-Horsley et al. indicated that context is complex, comprising many interconnected and dynamic influences. Nine features of the context that are important to consider are students, standard, and learning results; teachers and teachers' learning needs; curriculum, instruction, assessment practice, and learning environment; organizational culture; organizational structure and leadership; national, state, local policies; available resources; history of PD; and parents and the community. Critical issues include the third input that plays a role in the set goals phase. Loucks-Horsley et al. indicated that the critical issues are the "tough nuts" (p.9) that professional developers work to crack as they design and provide learning experiences for teachers. According to the PD design framework, professional developers consider a range of strategies to use in PD at the

planning phase. Loucks-Horsley et al. described 18 different strategies for PD that lead to different outcomes. These PD strategies are shown in the Table 2.

Table 2

Eighteen Strategies for Professional Learning

Aligning and implementing curriculum
Curriculum alignment and instructional materials selection
Curriculum implementation
Curriculum replacement units
Collaborative structures
Partnerships with scientists and mathematicians in business, industry, and universities
Professional networks
Study groups
Examining teaching and learning
Action research
Case discussions
Examining student work and thinking and scoring assessments
Lesson study
Immersion experiences
Immersion in inquiry in science and problem solving in mathematics
Immersion into the world of scientists and mathematicians
Practicing teaching
Coaching
Demonstration lessons
Mentoring
Vehicles and mechanisms
Developing professional developers
Technology for professional development
Workshops, institutes, courses, and seminars

Lee, Wang, Musikul, and Abell (2006, March) conducted a study to examine the process of designing and implementing science teacher PD by purposefully selecting one PD project as a case to consider in light of a theoretical framework for effective PD design (Loucks-Horsley et al., 2003). The findings of this study supported the Loucks-Horsley et al.'s model (Figure 3) in many ways. However, there were instances when the case deviated. This model implied that established goals should inform chosen PD

strategies. However, Lee et al. found evidence that inputs did enter the phases as the theoretical model proposed. The exception was when PD strategies were first considered. In that case, PD strategies were a consideration embedded within the goal setting phase rather than distinctly impacting subsequent planning once the goals were set. They also found that the box labeled as “Plan” in the Loucks-Horsley et al.’s model was somewhat unclear. This phase of planning could encompass both the overall blueprint for design and the additionally planned details for ‘doing the PD’ with teachers. Moreover, given that the boxes collectively represent the generic planning sequence, exactly what the “Plan” phase entails is ambiguous. This study found that there was not a clear distinction between when and how these first three phases of planning were enacted.

Characteristics of Effective Professional Development

Standard-based. The National Research Council, NRC (1996) posited the need for PD within their standards documents. For example, the *National Science Education Standards* (NRC, 1996) presented four standards for professional developers to consider when designing PD for science teachers. Overall, the vision of the national science education standards is to provide teachers with opportunities to engage in the practice of science themselves; reflect on this practice with respect to their classroom teaching and interaction with their students; and improve their content and pedagogical content knowledge. From a content-generic perspective on PD, the National Staff Development Council [NSDC] (2001) provided 12 standards for the design of PD organized into three categories - context, process, and content. Each category focuses on the goal of PD to improve the learning of all students.

The standards for the effective PD described by the NRC and the NSDC are summarized in the Table 3.

Table 3

Summary of the Effective PD Defined by the Standards

Standards for Staff Development (NSDC, 2001)	National Science Education Standards (NRC, 1996)
<p>Context</p> <ul style="list-style-type: none"> • Organize learning communities and align goals with school and district. • Require school and district personnel to become leaders. • Provide necessary resources to support adult learning and collaboration. 	<p>Standard A: Science Content PD experiences for teachers must build on the teacher's current science understanding, ability, and attitudes.</p> <p>Standard B: PCK PD experiences for teachers of science must use inquiry, reflection, interpretation of research, modeling, and guided practice to help science teaching.</p>
<p>Process</p> <ul style="list-style-type: none"> • Use student data to determine learning priorities, monitor progress and help sustain improvement. • Use multiple sources for evaluation. • Apply research to decision making • Select learning strategies appropriate to the intended goal. • Apply learning theories. • Collaboration among content and education specialists. 	<p>Standard C: Promoting lifelong learning. PD activities must provide regular, frequent opportunities for individual and collegial examination and reflection on teaching practice.</p>
<p>Content</p> <ul style="list-style-type: none"> • Prepare teachers to provide equitable learning experiences for students. • Improve the quality of teaching by deepening teacher content knowledge; modeling research-based instructional strategies; and preparing teachers to use various forms of classroom assessment. • Provide educators with knowledge and skills to involve families and other stakeholders. 	<p>Standard D: Coherent and integrated design the PD experience. PD must integrate and coordinate program components; recognize individual and group interests, as well as the various needs of teachers; collaborate among all stakeholders; recognition of the history, culture, and organize the school environment; and do continuous formative and summative evaluations of the PD program.</p>

Research-based. Educational researchers have learned a great deal about what comprises effective professional development. For example Loucks-Horseley et al. (2003) described that a quality PD should (a) emphasize inquiry-based learning, investigations, problem-solving and application of knowledge, (b) provide opportunities for teachers to build knowledge and skills and examine practice critically, (c) engage teachers in the learning approaches they will use with their students, (d) provide opportunities for teachers to work with their colleagues and other experts, (e) support teachers to serve in leadership roles, and (f) give priority to student learning. The PD designers should consider the balance among topics to cover, number of activities, and times for discussion and collaboration with other teachers in improve their practice.

Thompson and Zeuli (1999) asserted that PD participants must experience a sufficient amount of dissonance to disturb their existing beliefs, knowledge, and experiences with learning and teaching. Thompson and Zeuli explained that providing teachers with this type of *transformative* learning experience requires the following: (1) create a high level of cognitive dissonance; (2) provide sufficient time, structure, and support for teachers to think through the dissonance experienced; (3) embed the dissonance creating and resolving activities in teachers' situations and practices; (4) enable teachers to develop a new repertoire of practice that fits with their new understanding; and (5) engage teachers in a continuous process of improvement. The professional development should prepare teachers in terms of being able to present and explain the current scientific model clearly and to contrast it with student models (Anderson & Mitchener, 1994) and being able to help students connect their new information to their prior knowledge.

Guskey (2003) reviewed 13 lists of characteristics of effective PD from publications produced by various research and policy organizations (e.g., Association for Supervision and Curriculum Development, Educational Research Service, Eisenhower Professional Development Program). From these lists, he identified 21 attributes of effective PD. Of these attributes, he focused much of his discussion on the five most frequently mentioned: 1) enhancing teachers' content and pedagogical knowledge, 2) providing sufficient time and other resources, 3) promoting collegial and collaborative exchange, 4) establishing procedures for evaluating the PD experience, and 5) conducting school or site-based PD. However, Guskey argued that there is a significant amount of research that asserts that school or site-based PD is not as important as once thought. Rather, "a carefully organized collaboration between site-based educators, who are keenly aware of critical contextual characteristics and district-level personnel, who have broader perspectives on problems, seems essential to optimize the effectiveness of professional development" (Guskey, 2003, p. 749), not necessarily the location of the PD itself.

A common element of effective PD discussed across the literature is the need for sustained support for teachers as they return to their schools to implement the PD objectives (Desimone, Porter, Garet, Yoon, & Birman, 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001; Guskey, 2003; Loucks-Horseley, Love, Stiles, Mundry, & Hewson, 2003; Thompson & Zeuli, 1999). An important aspect of providing this sustained support is the development of a network of communication between PD facilitators and teachers, and among the teachers themselves. Jauhainen, Lavonen, Koponen, and Suonio (2002) explained that when teachers return to their schools, lines of

communication are critical for continuing to develop the knowledge and skills addressed during the PD experience. Classroom change depends on providing extended support throughout the school year with opportunities for teachers to collaborate and reflect on their own beliefs and practices (Borasi, Fonzi, Smith, & Rose, 1999).

Despite the consensus about effective PD suggested by research and policy, a disparity between theory and practice still exists. Loucks-Horsley et al. (2003) claimed that PD for science and mathematics teachers (a) lacks in the number and variety of opportunities for educators to participate; (b) is not aligned to the needs or learning goals emphasized in education reform; (c) is insufficient in providing sustained support to educators; (d) focuses on how to change the individual educator rather than organization/school; and (e) provides pockets of innovation with minimal means for impact at the classroom and system levels. Research indicates that teachers could not change instruction in reform-minded ways simply by being told to do so. Teachers would need opportunities to reconsider their current practices and to examine others, as well as to learn more about the subjects and students they teach (Ball & Cohen, 1999; Guskey & Sparks, 1996; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). Many PD experiences are intellectually superficial and disconnected from deep issues of curriculum and learning, fragmented, and non-cumulative (Ball & Cohen, 1999). Rarely are PD experiences based on a curricular view of teachers' learning. Teachers are taught to need updating rather than have opportunities for serious and sustained learning of curriculum, students, and teaching. Many researches found that experienced teachers adopted a reform-based curriculum superficially, then continued to teach in traditional ways (Keys & Kennedy, 1999; Olson, 1981; Welch, Klopfer, Aikenhead, & Robinson, 1981). Such

research indicates that teachers could not change instruction in reform-minded ways simply by being told to do so. Teachers would need opportunities to reconsider their current practices and to examine others, as well as to learn more about the subjects and students they teach (Ball & Cohen, 1999; Guskey, 2000; Loucks-Horseley, Love, Stiles, Mundry, & Hewson, 2003). However, most PD delivered through short-term sessions and workshops that often lack depth, do not address serious issues related to curriculum and learning are disjointed and non-cumulative (Ball & Cohen, 1999). Rarely do these professional development opportunities seem to be based on a curricular view of teachers' learning. Teachers are taught to need updating rather than opportunities for serious and sustained learning of curriculum, students, and teaching.

In Thailand, the science curriculum has been designed and constructed to respond to the local needs and environment (Soydhurum, 2001) and PD has been designed to facilitate the implementation of that curriculum. There are a number teacher PD programs, particularly inservice training, that are conducted in Thailand. The previous PD programs for teacher PD in Thailand were usually organized by the central agencies in a city and took place in a very short time without consistent monitoring and evaluation (Office of the National Education Commission, 2004). The general consensus amongst educators, parents, and students is that the quality of teachers has regressed considerably in recent years (Sinlarat, 1999). Initially, the Government took action by establishing the Institute for the Promotion of the Teaching of Science and Technology (IPST), charged with the mission to develop quality teachers for mathematics and science (Soydhurum, 2001) and commission projects to provide quality education to rural area. Thus, IPST is entrusted with the duties and responsibilities in developing science, mathematics and

computer curricula, activities and textbooks, and instructional kits in accordance with the prescribed guidelines as stipulated in the National Education Act (Sriphan, 2002). One of the responsibilities of IPST is to develop the teaching profession for K-12 science and mathematics. In regards to the Science Strand, five departments are charged to take care of science curricula and professional development (Soydhurum, 2001):

- Department of Primary Science: oversees the science curriculum for K-6 students and professional development for primary teachers across the country.
- Department of Secondary: oversees the science curriculum for grades 7-9 and professional development for teachers of grades 7-9 across the country.
- Department of Physics: oversees the curriculum of physics for grades 10-12 and also professional development for secondary teachers who teach physics across the country.
- Department of Chemistry: oversees the curriculum of chemistry for grades 10-12 and also professional development for secondary teachers who teach chemistry across the country.
- Department of Biology: oversees the curriculum of biology for grades 10-12 and also professional development for secondary teachers who teach biology across the country.

The decline of quality in Thai teacher development is not new, but the search for appropriate solutions has not been very successful (Office of the National Education Commission, 2004). The continuous poor performance of Thai children in many international tests such as TIMSS and PISA (Soydhurum, 2001) is further evidence of the eroding quality in education. Although many K-12 teachers have participated in PD

workshops and seminars, the evaluation of the PD design and its outcome has been lacking. Most of the evaluations are informal and occur during the PD implementation when the PD providers interact with teachers. Although some PD projects administer a survey to the participants, the majority of the questions ask about teachers' satisfaction with the PD and their recommendations for improvement and do not address the other 4 levels of Guskeys (2003) PD evaluation model. Some PD programs, such as the PD for master teachers or leader teachers, provide a post-test to participants after the PD programs in order to evaluate teachers' learning of science content.

Thai professional developers often employ traditional teaching strategies during the PD delivery. Strategies such as debates, brainstorming, excursions, independent work, emphasis on explanation and reasoning were not discussed or demonstrated in many PD projects (Piya-Ajariya, 2001). Although the stakeholders agree that PD is important to improve teachers' knowledge and practice, PD in Thailand currently does not help teachers build the knowledge, skills, and dispositions necessary to help students construct their knowledge in science (Piya-Ajariya, 2001). The connection between theory and practice in PD is not fully appreciated nor well implemented or evaluated.

Professional Development Strategies

Although the ultimate goal of Professional development is to improve student learning (Hewson, 2007), teachers are central to the process of curriculum reform. To effectively teach a particular subject including science, a teacher should have solid knowledge base for teaching, which includes subject matter knowledge, pedagogical knowledge, pedagogical content knowledge, knowledge about school setting and learners (Shulman, 1986). Based on this concept, PD plays an essential role in successful

education reform. Professional developers should match the strategies to the needs of teachers in order to help them develop all knowledge bases necessary for teaching. Loucks-Horsley et al. (2003) suggested that “strategies in isolation do not constitute effective professional development” (p. 111). Each strategy is one piece of the puzzle in meeting the specific goals and context. Thus, effective PD should plan to use a variety of strategies in combination with one another to form a unique design (Loucks-Horsley et al., 2003). The two PD strategies--curriculum implementation and immersion in inquiry in science-- are based on Loucks-Horsley et al summarized in Table 2. I reviewed these two strategies because they were frequently used by the professional developers in Thailand.

Curriculum Implementation. Curriculum implementation is a strategy aimed to help teachers learn new curriculum, activities, teaching methods, and how to implement them in the classroom. This strategy allows teachers to reflect on and share information about teaching and learning the new curriculum in the context of implementing the curriculum with their colleagues or students. In addition, teachers must learn science content, material management, curriculum teaching, and assessment on their own and students’ learning. This strategy benefits PD and teachers as it is a vehicle in aligning teachers’ learning contents, materials, and teaching strategies to classroom practice (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). An important concern in introducing a new curriculum to teachers is that professional developers and school administrator must plan to support the teachers’ implementation of the new curriculum and to ensure that the teachers continued to use this curriculum after the initial phase.

Dass (2001) studied a PD program that used this strategy. He interviewed 24 teacher participants in the Collier Chautauqua Program (CCP) and the dissemination efforts of the Iowa Chautauqua Program after the first year of implementation. This program provided a 3-week institute for participating teachers to experience constructivist teaching through a Science-Technology-Society Curriculum. This workshop was delivered by lead teachers, university staff, and scientists. They also provided a series of workshops in the fall and spring, monthly meetings, electronic communication, and school visitations. The participants were required to work in teams to develop a 5-day teaching module and implement it in their classrooms. In the call-back sessions in fall and spring, the teachers were asked to review the problems with the module, analyze their current practice and their experiences in constructivist teaching using the module as a frame of reference. In regard to the teachers' expression about their implementation STS curriculum, many teachers were more familiar with their previous curriculum (FOSS) than with STS (which they had to spend more time in implementing). They stated that the STS curriculum demanded new ways of assessment and unless assessment practices changed concurrently, they were not motivated to fully implement these instructional approaches. The teachers also mentioned materials, resources, and students' maturity as constraints. Although the teachers stated that by using technology and having more interconnection with nature they saw some improvements among students such as in their reading ability, they were not sure the students really learned. Dass indicated that the teachers attended a 3-week summer workshop doing STS activities, creating a teaching module, and connecting science to technology and society. However, they lacked an opportunity to develop other knowledge for teaching such as

knowledge of students and of assessment. This led to problems when the teachers implemented the curriculum in their classroom. They indicated that they were not sure whether or not students were learning and the assessment was not effective to the new teaching approach. In addition, the teachers in this study also expressed concern about how the schools or district will support this implementation. Thus, the teachers did not fully implement the curriculum since they did not know if they had to revert back to the old curriculum.

Another PD project called Learning Technologies in Urban Schools (LeTUS), was a collaboration between the University of Michigan and Detroit Public Schools to promote standards-based middle school student learning in science (Kubitskey, Fishman, & Marx, 2003; Margerum-Leys, Fishman, & Peek-Brown, 2004). Together, university staff worked with school partners to create a curriculum that emphasized process in addition to science content. Then, the school teachers piloted the materials and provided feedback for researchers to revise the curriculum. The goals of the PD were to have teachers improve their knowledge of technology and enhance knowledge of content and pedagogy, comfort with curriculum, and implement it (Kubitskey, Fishman, & Marx, 2003). The PD designers used five strategies in a series of five workshops to meet their goals: direct instruction, peer exchange, model teaching, curriculum review, and planning the unit. The findings showed that model teaching impacted teachers' learning while peer exchange allowed the teachers an opportunity to interrogate and reflect on practice with the community. In contrast, direct instruction did not have much impact on teachers' expressed learning. According to the teachers' reflections, PD staff shifted strategies by reducing direct instruction and increasing peer exchange in the following workshops. The

researchers observed classroom teaching of three teachers after PD participation. All teachers enacted the activity as modeled at the workshop except for one teacher who modified the activity to meet the needs of her classroom. The results also showed that two of the three teachers had limited science knowledge that influenced their abilities to respond to students' questions. The researchers concluded that model teaching and peer exchange strategies impacted teacher learning and their implementation in the classroom, but they suggested other forms of PD to help teachers develop in-depth content knowledge.

Immersion in Inquiry in Science. Immersion in inquiry in science is the structured opportunity for teachers to directly experience science content and process. First, by becoming a learner, teachers deepen their own understanding of the science content that they are teaching their students. Second, by experiencing the processes for themselves, teachers are better prepared to help students become active, engaged inquirers. Using this strategy is based on the assumption that teachers benefit from experiences grounded on the same principles that they are expected to implement with students. Thus, the key element of immersion in inquiry in science is to provide intensive experience to teachers in building science content knowledge and process as learners. Just as students learn best when they are actively engaged in their learning, teachers are most likely to internalize science concepts and teaching methodologies when both their hands and minds are engaged in the process. The goals of PD using immersion in inquiry as a strategy include having teachers develop beliefs and practices conducive to the implementation of inquiry lessons through an inquiry learning approach (Radford, 1998), getting to know teaching

practice in action, examining, and reflecting upon their enacted lessons (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003).

Radford (1998) studied the effect of a PD program on teacher participants' science content knowledge, process skills, and attitudes toward science teaching. A 3-week intensive summer workshop focused on integrating concepts from life and environmental science, chemistry, and mathematics. The teachers engaged in hands-on and minds-on activities, learning science and science process skills. Within small groups, teachers explored, discussed, and explained their interpretations to each other. They also had to present their data to the group, which often led to further exploration. The teachers were continually encouraged to use these techniques with their students. The researcher compared attitudes and science process skills of students of trained teachers and non-trained teachers. The results showed that the students of trained teachers had consistently greater achievement in process skills and more positive attitude toward science and their science classroom experiences than the students of non-trained teachers. The students also mentioned that they conducted more experiments and learned more science. During the interviews, the teachers mentioned that the project activities helped them learn more science content and helped them gain confidence in teaching their students through inquiry-based science.

A study by Luft (2001) measured preservice and inservice teachers' beliefs and classroom practices after they participated an inquiry-based PD. The study showed that the preservice teachers changed their beliefs toward inquiry-based teaching more than their practices, whereas the inservice teachers demonstrated greater change in practices than in beliefs. The students of inservice participants significantly improved in process

skills such as developing researchable questions, designing and conducting investigations, and sharing the results of investigations.

A similar study was done by Basista, Tomlin, Pennington, and Pugh (2001) to investigate a PD program that included a substantive and intensive summer institute integrating science content, pedagogical knowledge, and mathematics. The program included support through the academic year and classroom visitations. In the workshops, teachers experienced inquiry activities and compared these new experiences with traditional teaching methods. During the last two weeks of the institute, teachers in the same grade level worked as a group to develop a unit integrating mathematics and science. The study demonstrated that teachers developed depth of knowledge through inquiry activities in a cooperative learning environment. As in Luft's work, the teachers also felt that they gained more skills and confidence in how to use inquiry in their classroom. The students of these teachers were asked to complete a survey, which revealed that at the end of the academic year, students ranked science as one of the top three favorite subjects. However, the teachers expressed significant stress due to the combination of intensive content, pace, and time involved in the summer institute. The evaluation by the administrators revealed that the inquiry activities were particularly valuable but that the half-day format was not enough time for in-depth discussions.

Summary

Standards and studies have defined the characteristics of effective PD in terms of outcomes that it develops content knowledge and science PCK for the teachers. Effective PD also needs to provide lifelong learning. The PD design should be coherent and address the teachers' needs. The research also indicates that the effective PD engages

teachers in the learning approaches they will use with their students, provides opportunities for networking among teachers and experts, and supports teachers to serve in leadership roles. The ultimate goal in providing PD to the teachers is to improve student learning. However, the research reveals that many PD projects provide intellectually superficial content knowledge disconnected from important issues of curriculum and learning, and do not provide cumulative experiences for the teachers. According to these studies, we see that very little progress has been made in PD for science teaching and learning.

Gaps in the Literature

According to this review of literature on elementary science teaching, pedagogical content knowledge, and professional development, there are a number of gaps in the literature that need to be addressed. These gaps include (1) research on the professional developers' PCK, (2) research on PD in a holistic view, and (3) research about the PD context in Thailand.

Much of the literature defines PCK as a special form of knowledge that bundles knowledge of learners, learning, and pedagogy. This type of knowledge is necessary for teaching. A number of researchers have studied science PCK of science teachers in elementary, middle, and secondary schools. A few studies exist on the PCK of science teacher educators. However, very little research exists that investigates the PCK of professional developers, who have a significant role in providing inservice teacher education. Consequently, the findings from this study will help researchers understand PCK of professional developers, a heretofore unstudied part of both the PCK and PD literature.

Most researchers have studied PD design, implementation, and outcomes separately. This study is significant in that it aims to understand the dynamic of PD design, delivery, and outcomes by examining PD in a holistic manner. The findings from this study will help researchers and educators understand the holistic picture of PD in terms of professional developers' knowledge and orientations to professional development, the role of knowledge and orientations in PD design and delivery, PD and teacher learning, subsequent teacher practices, and the role of feedback to professional developers.

Finally, few researchers have studied PD in Thailand, especially in terms of how it was designed and delivered. The science curriculum in Thailand has been designed and constructed to respond to the local needs and environment. Consequently, the PD in Thailand has been designed to facilitate the implementation of that curriculum. This study will help the researchers and educators understand the PD context in Thailand.

CHAPTER THREE: THE RESEARCH PROCESS

Research Tradition

Qualitative research is a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible (Denzin & Lincoln, 1994). Unlike quantitative study, in which researchers identify sets of variables and seek to determine their relationships, qualitative studies are best at contributing to a greater understanding of perceptions, attitudes, and process (Glesne, 1999). Denzin and Lincoln (1994) stated that qualitative research involves the collection of a variety of empirical evidence that describes routine and problematic moments and meanings in individuals' lives. In this research, I utilized qualitative research methods to make sense of the complex world of professional development and teacher learning. I adopted a constructivist-interpretative paradigm as my research paradigm, acknowledging that there are multiple realities from which we construct meaning in real-world settings (Denzin & Lincoln, 1994). This study is grounded in a qualitative case study tradition that is appropriate for examining one or more individuals (Creswell, 2003; Yin, 2003). *How* and *why* questions were central in the case study to investigate a contemporary set of events within specified boundaries (Hatch, 2002) over which the researcher had little or no control (Yin, 2003). Schramm (1971) indicated that "the essence of a case study is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result" (as cited in Yin, 2003). Thus in this qualitative study, I examined one professional development project as a case, rather than analyzing cases of an individual professional developers and teachers. In this case, I tried to understand the dynamic nature of real events associated with a particular PD project in a holistic manner.

The research constructivist perspective to qualitative has ontological, epistemological, and methodological assumptions. In regard to my ontological perspective, I believe that knowledge is subjective, absolute realities are unknowable. The objects of inquiry are individual perspectives or constructions of reality. They are relative depending on context and person. I also hold an epistemological perspective associated with my constructivist paradigm. I believe that knowledge is a human construction that the researcher and participants co-construct understandings (Hatch, 2002). Also, knowledge is developed through negotiation (Patton, 2002, p. 203). Patton (2002) described that knowledge and agreement result from dialogue. Thus, PD researchers might seek to understand the aims of practice from a variety of perspectives, or with different lenses. My constructivist perspective has methodology implication. A case study is appropriate for this study because this study is an exploration of a bounded system or a case over time through detailed, in-depth data collection involving multiple sources of information rich in context (Creswell, 1998). In a case study, the relevant behaviors cannot be manipulated. Researchers use case studies to contribute to knowledge of individuals, groups, organizations, societies, and related phenomena (Yin, 2003). In this research, the case study method allowed me to retain the holistic and meaningful characteristics of real-life events in PD.

Purpose and Research Questions

The purpose of this research was to investigate the dynamic nature of PD in Thailand and its consequences in terms of how science professional developers' orientations to PD, and knowledge of PD, teachers, science curriculum, instructional strategies, and assessment (PCK) play role in PD design and delivery. I also investigated

the relations of PD to participants' orientations to primary science teaching and their knowledge of students, science curriculum, instructional strategies, and assessment. Finally, I explored the relationship between teachers' implementation and science professional developers' PCK. Thus, this qualitative research examined an entire Thai PD project including design, implementation, and outcomes, as a case to understand the relations within science PD in a holistic manner as shown in Figure 4.

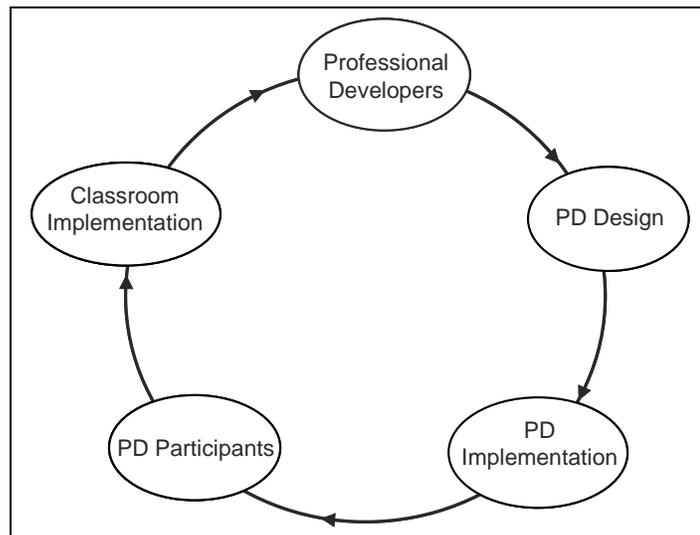


Figure 4. The Dynamic of Professional Development

I used Figure 4 to represent the holistic view of PD, including professional developers' orientations and PCK for PD, and other factors that influence their PCK. The holistic view of PD also allowed me to understand the relation of PD to teachers' learning and teaching science in their classroom. However it is important to note that teachers' learning and teaching undoubtedly influenced by other factors that were outside of the PD setting and thus beyond my research questions.

The overarching research question was: What knowledge, orientations, and practices do science professional developers and professional development participants

have and what are the consequences of these understandings? Sub-questions that guided the study were:

1. What are professional developers' orientations to professional development?
2. What do professional developers know about teachers, curriculum, instructional strategies, and assessment for professional development?
3. What knowledge do professional developers take into account during the professional development design process?
4. What happens during the professional development workshop?
5. What happens during classroom teaching that takes place after professional development?
6. What are professional development participants' orientations to science teaching?
7. What do professional development participant know about students, curriculum, instructional strategies, and assessment for science teaching?

Figure 5 shows how each sub-question guided my inquiry throughout the entire process of data collection

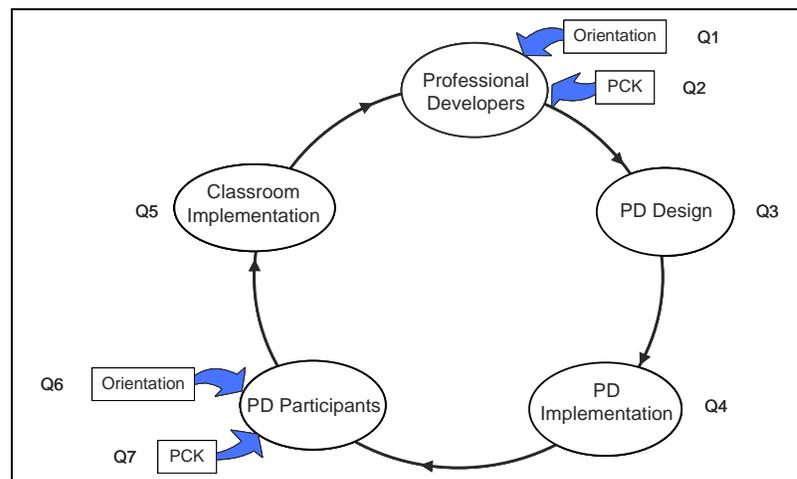


Figure 5. Research Questions by PD Dynamic

Context of the Study

Since its inception, the Institute for the Promotion of Teaching Science and Technology (IPST)'s mission has been the development and continuing improvement of science curricula and science instruction. Before the science education reform in Thailand, IPST developed a National Science Education Standards and National Science Curricula for K-12 grades. At that time, science was not a separate subject, but was subsumed in the Life Experiences subject. Currently, science is now a separate subject and IPST still has a responsibility in developing science curricula for K-12 grades. However, the Thai government does not limit schools to adopt only the IPST curricula as the National Curricula in science teaching. The schools are free to select other curricula from the private companies. In spite of this latitude given to schools, IPST still has responsibility in developing the National Science Education Standards for K-12. However, as one of many curriculum choices on the market, the development of science curricula in Thailand is highly competitive.

IPST still maintains a role in providing professional development to K-12 teachers. In general, the each department, including the Department of Primary Science at IPST, develop a year-long plan outlining professional development (PD) for public schools teachers and borderline police who volunteer to be the teachers in the borderline schools. To provide PD for the teachers, the staff of the Department of Primary Science developed a PD project proposal researching a budget from IPST in organizing the PD, which IPST has already included in their overall plan. The budget normally includes PD participants' stipend, materials and handbook, and expenses for lodging and food.

In this case, the private schools requested for the Department of Primary Science an opportunity to provide PD to the private school teachers, although normally providing PD for private school teachers is not the responsibility of IPST. IPST has responsibility to provide PD for teachers from the public schools across the country. However, because of the request of the private schools, the Department of Primary Science developed a PD project proposal to IPST to ask for the authorization and some budget. In contrast to the public school teachers, the private schools teachers who attended PD did not receive stipends. In addition, they were required to pay for the registration fees. The details about specific context of this PD project are provided in the next Chapter.

In order to better understand the context of the teacher participants in the private school PD, I have summarized the typical differences between the public schools and private schools in Table 4.

Table 4

The Differences between Private and Public Schools in Thailand

Private Schools	Public Schools
<ul style="list-style-type: none"> • Managed by owner of schools following Private School Act 	<ul style="list-style-type: none"> • Managed by school principals of the government following National Basic Education Act
<ul style="list-style-type: none"> • Owners of school make curricular decisions 	<ul style="list-style-type: none"> • The school principals need to ask for authorization from the government or follow rules before making any curricular decisions
<ul style="list-style-type: none"> • Have a lot of money for buying instructional materials 	<ul style="list-style-type: none"> • Inadequate instructional materials
<ul style="list-style-type: none"> • Lower class size (about 30 students) 	<ul style="list-style-type: none"> • Higher class size (about 40-50 students)
<ul style="list-style-type: none"> • Have teachers with science education background who teach primary science 	<ul style="list-style-type: none"> • Lack of science teachers to teach primary science

The data was collected in Thailand from August through October of 2006. Participants included four professional developers from the Department of Primary Science at IPST and four elementary teachers who participated in the PD project. In August, 2006, the Department of Primary Science recruited 1st – 6th grade elementary teachers from private schools across the country to receive PD. The PD project proposal indicated that goals of this PD were (1) to increase teachers' knowledge and first-hand experiences in a reform science teaching; (2) to promote teachers' abilities in conducting science instruction; (3) to promote collaborations among teachers; and (4) to improve teachers' confidence in teaching science. This PD was a 3-day workshop that addressed several science concepts in physics, chemistry, biology, and earth science. These topics comprise half of the science curriculum at any elementary grade level. The chemistry topics in the PD project included material, the property of material, matter and state of matter, and matter and changes. There were two physics sections in this PD: one was sound and electricity, and another one was light, force, and movement. The section I decided to observe was sound and electricity section.

Professional Developer Participants

The four professional developers were from the Department of Primary Science, IPST. The reason I selected these four professional developers was because I had worked at the Department of Primary Science for two years before I started my Ph.D. program. My tasks were to develop chemistry curricula for the primary grades (1-6) in Thailand and to provide PD for primary science teachers. In addition, I will return to my IPST position after graduation. I purposefully selected these four professional developers

because they taught physical science lessons in the PD, which related to my former and future career.

Throughout this study I use the pseudonyms Sommit, Piti, Somsri, and Vimon to identify these professional developer participants. Sommit and Somsri designed and carried out the chemistry units while Piti and Vimon designed and implemented the sound and electricity units. I previously worked with Piti and Vimon for two years and with Sommit and Somsri for a year. Piti was once a secondary school teacher, but now is a staff member of IPST. He had more than 15 years of experience in teaching physics before being employed with IPST in 2001. His responsibility is creating physics activity books for student and the teaching manuals for teachers, and providing PD for primary teachers on physics concepts. He also trained Vimon to become a professional developer in regards to the electricity unit.

Likewise, Sommit has worked at IPST for 10 years. He is responsible for developing chemistry activity books for students and teaching manuals for teachers, and providing PD for primary teachers on chemistry concepts. He has many years of experience in providing PD to teachers. Like Piti, Somsri was a former secondary school teacher and a school administrator, who retired eight years prior to the study. Somsri is a part-time staff member of IPST. She started working at Department of Primary Science in 2002 as an academic specialist. Her former task was to advise IPST staff about chemistry concepts and pedagogical strategies for teaching at elementary levels. Somsri was also part of a team that developed activity books for students and teaching manuals for teachers in chemistry. Somsri rarely participated with PD planning and implementation. However, because of my absence, the Department of Primary Science did not have

enough staff to take care of PD in chemistry, and, thus, Somsri was asked to be part of the chemistry PD team.

The last professional developer in this study, Vimon, is a new breed of Department of Primary Science staff. Vimon graduated with a B.S. in physics. She had worked at IPST since 2001 as a support staff following her graduation from the university. Vimon was then promoted to be an academic staff member and was trained by her colleague, Piti, to become a professional developer responsible for the electricity unit. Vimon has 2 years of experience as a professional developer, but no experience in classroom teaching. The professional developers in the Physics team assigned Vimon to take responsibility for the electricity unit because this was her major at college.

Teacher Participants

In the selection of teacher participants, I asked IPST staff for a list of teachers who registered for the PD. I never worked or met these teachers before I received the list from IPST. I purposefully selected teacher participants based on the following criteria: (1) the teachers taught in upper elementary grades (4-6) where most physical science units are taught; (2) each teacher planned to teach at least one PD unit during August-October, the period of my classroom observation; and if possible (3) teachers had similar ranges of teaching experience in science. I also looked for a sample in geographically convenient locations, given the difficulties of travel in Bangkok. On the first day of PD before the first session, I asked several teachers to meet me in a small meeting room so that I could explain my study. Some teachers declined to participate in this study because they were afraid of an overload of work. Some teachers wanted to participate in the study but did not meet the criteria above. I found four teachers whom I gave the pseudonyms

Manee, Chujai, Jinda, and Wanna throughout the study. The four teacher participants were from different four private schools located in Bangkok. After I informally received permission from the teachers, I contacted the school principals of these teachers personally to explain the goals and steps of my data collection. Then, I gave the principals a permission letter and form to sign in order to allow their colleagues to participate in the study (Appendix A).

Similar to the professional developers, I personally contacted each teacher again in order to invite them formally to be the participants of this study. I also asked them to complete the inform consent which required their signature before beginning the study (Appendix B).

I first contacted Manee. I did not know her before PD. Manee worked at Smarty Kids Primary School. She has taught science to grades 4-6 for five years. When I asked her to recall her experiences in science as a learner, she mentioned that she only remembered that she learned science and did science activities when she was at middle school. During the school term in which I observed, Manee taught the topic of matter and states of matter and the sound units to students in grade 5.

Chujai was a beginning teacher at Sunshine Primary School. She only had six months experience in teaching science. Before becoming a full-time teacher, she taught at Demonstration School for one school term for her teaching internship. However, she taught at middle school levels rather than elementary. At Sunshine, Chujai taught science to students in grades 4-6. When recalling her experience in science as a learner, she mentioned that she began to learn science during the primary level and thought science was fun because her teacher usually took students outside classroom. The unit that Chujai

taught after the PD was heat conduction unit to 5th grade students. She mentioned that this was her first time teaching this unit to elementary students.

Jinda has taught science for 10 years. She has taught at Best East Primary School for two years. She graduated in chemistry education for the secondary level. However, she has never taught secondary science. She would rather teach at the primary level because she believed that older level students needed to study harder, and she was not sure whether she could help those students. Jinda stated that she did not do much in science when she was an elementary student. She only sat and listened to the teachers who talked about science. During the study, Jinda taught the sound unit to students at grade 5.

The final teacher participant, Wanna, taught at Happy Child Primary School. She has taught science for 10 years. She taught kindergarten students and also 4th-6th grade students. At the kindergarten level, she taught every subject. In grades 4-6, she only taught science. Similar to Jinda, Wanna mentioned that there was nothing much in science class when she was in primary school. There were no science activities, only a book to read and memorize. She remembered that she did science when she was at college. Wanna taught the matter and states of matter units to grade 5 students during this study.

Informed Consent

To gain access with the professional developers, I first contacted the president of IPST and the head of the Department of Primary Science to explain the goals of this research and the process of data collection and data analysis. Then I gave a letter to the IPST president in order to allow me to conduct a study involving his colleagues

(Appendix C). The next step was to make personal contact with Sommit, Piti, Somsri, and Vimon to explain my research study and asked them to sign the inform consent form (Appendix D). The meeting with these professional developers was different then the meetings with the IPST president or department head. I needed to spend more time in explaining the research and how I was going to report the study. At first, these professional developers were concerned that the report of this research might put them at risk. Once I clearly explained the purpose and processes of this research, the professional developers felt more comfortable to participate in this study.

To gain access with the teachers, I first contacted the school principals to explain the goals of this research. Then I gave a letter to the school principals in order to allow me to conduct a study involving his colleagues (Appendix A). During the first meeting with the teacher participants, I asked them to read the informed consent letter (Appendix B) and I explained that their participation was voluntary. I explained to them that their refusal to participate involved no penalty or loss of benefits to which they were otherwise entitled. In addition, they were able to discontinue their participation at any time without penalty or loss of benefits. Also, they were not obligated to answer every question that they were asked. Then I asked the participants to sign the consent form.

To understand PD in a holistic manner, it was necessary to investigate an entire PD process including design, implementation, outcomes, and reflection. Thus, I also asked permission from teacher participants to share video clips of their classroom teaching with the professional developers. The purpose of sharing the clips was to investigate the professional developers' reactions to the teachers' implementation in their classroom and the consequences to their orientations to PD. After explaining the

necessity of audio and video taping, all professional developers agreed to let me tape their interviews and PD sessions. All teacher participants allowed me to audio tape their interviews, while three teacher participants, Manee, Chujai, and Jinda, allowed me to video tape their teaching. Only Wanna did not agree to let me video tape her teaching, but did allow me to audio tape the interviews. Also, she allowed me to take field notes during the observations. All audio and video tapes from this project will be kept on file for three years and all participants' responses will be kept confidential. I informed all the participants that I would not report any results in a manner that would allow a reader to associate any responses to an individual respondent. Thus, participating in this study would subject participants to no risks greater than those they normally encountered in everyday life.

Design of the Study

Role of Researcher

As a constructivist, I believe that knowledge is constructed and not objective. Thus, researchers and participants join together in the process of knowledge construction. To develop a deeper understanding in this case study, I used both formal and informal collaborations. The formal collaborations occurred during the interview while the informal collaborations occurred during lunch time, breaks, and before and after observations. The informal collaborations helped me and the participants co-construct an understanding of what was happening in the research context.

Patton (2002) described variations in observer involvement: participant observer, onlooker observer, or both. Patton (p. 265) explained that the onlooker observer is one who completely separates himself or herself from the research settings as a spectator

does; the participant observer immerses himself or herself in the research setting as a full participant. In regards to my observations, I defined myself in the research settings as an onlooker observer throughout the observation process in order to see and hear phenomena occur within context. Lincoln and Guba (1985) indicated that building and maintaining trust is an important task for qualitative researchers. Once the researchers have the trust of their participants, the study will proceed smoothly.

I entered this project with numerous experiences as a researcher in many PD projects, including the Evaluation PD Projects Cycle 1&2 (Park Rogers et al., accepted), the Effective PD project (Pareja, Musikul, Ritzka, Abell, & Chval, 2006, January), a pilot study of Thai primary school teachers' and professional developers' views of science teaching and PD (Musikul & Abell, 2006, January), and a case study to understand PD design and implementation (Lee, Wang, Musikul, & Abell, 2006, March). In addition, during my doctoral program I had experiences and developed awareness about primary science teaching through the internships and independent study. Based on my knowledge of primary science education and PD, and my experiences in doing research, I believe that I am qualified to conduct this research and bring a unique perspective to the interpretations.

At the beginning of my data collection phase, I contacted all the participants on an individual basis in order to carefully explain my research goals and activities, build relationship, and develop trust between myself and the participants. In addition, to clarify my role as a researcher, I met the four IPST professional developers and participating teachers about one week prior to data collection in order to help familiarize them with my intentions and role.

Data Collection

I collected data at four different transition points: (a) during the design of PD, (b) at the PD implementation, (c) in teacher participants' classroom after the PD, and (d) after the teachers' classroom implementation. Figure 6 shows that I used several primary data sources to answer my research questions at different transition points of my data collection.

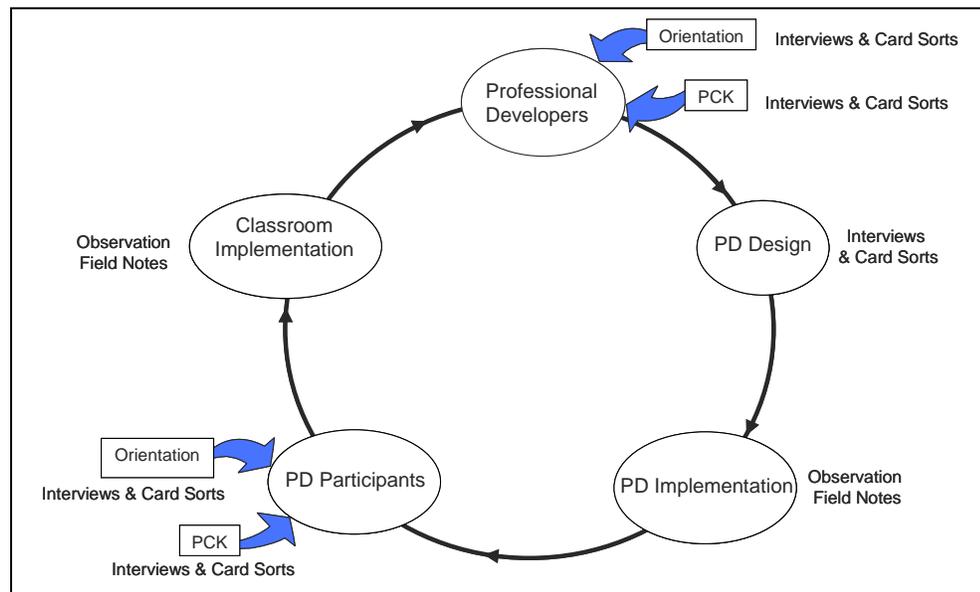


Figure 6. The Data Sources for Answering the Research Questions by PD Dynamic

During the design of PD, I met with Sommit, Piti, Somsri, and Vimon to talk to them about their plan and examined the material they prepared for PD activities. I also collected and reviewed PD curriculum and other documents that they were going to give to PD participants. At the PD implementation, as an onlooker observer, I observed both professional developer and teacher participants. At the end of PD, I attended each teacher's class and observed their teaching. Finally, I returned to IPST to have the professional developer participants view the video tape of teachers teaching science units. I utilized several methods of data collection to achieve a better understanding of the

participants' knowledge and experience, and to increase the validity of the research through triangulation of the data sources.

Interviews

In a qualitative study, researchers utilize interviews to uncover the meaning structures that participants use to organize their experiences and make sense of their worlds. This technique helps the researcher to bring the structures and meanings that are often hidden from direct observation to the surface (Hatch, 2002, p. 91).

I used interviews as a primary data source for the study. I developed and used open-ended interview protocols with the participants in order to allow them to recall and reconstruct their experience within the areas of interest for this study. The interview approach that I used in this study was the semi-structured interview (Patton, 2002). I conducted the interviews with guiding questions, but also followed the responses of participants with probing questions (Hatch, 2002; Patton, 2002). Thus, while a number of basic questions were worded precisely in a predetermined fashion, gave myself more flexibility in exploring certain subjects in greater depth or even undertaking whole new areas of inquiry that were not originally included in the interview instrument.

Professional developer interviews. I conducted three interviews with each professional developer participants. I also performed card sort activity (as shown in Table 4) with the professional developers at the same time with the first and the second interviews. The first interview (Appendix E) was in July 2006 when the professional developers were designing the PD. The focus of this interview was to gather data to understand professional developers' orientations to professional development, their knowledge about teachers, curriculum, instructional strategies, and assessment for PD,

and knowledge that they took into account during the PD design process. I conducted the first interview with each professional developer individually and also performed the card sort activity (as shown in Table 4) at the same time.

I interviewed the professional developers again following the PD implementation. The purpose of the second interview was to explore in more depth how the professional developers discussed their PCK in light of the PD. The second interview (Appendix E) included the card sort activity focused on the professional developers' experience with this PD itself and compared it to previous PD experiences. In this interview, I used a stimulated recall method (Calderhead, 1996) to gain access to the professional developers' thought processes. I developed a set of questions guided by my observation of their PD implementation. The purpose of these questions was to ask about a particular activity, teaching method, or questions that they used during the PD to encourage them to reflect on their teaching and the knowledge they used.

The third interview (Appendix E) with professional developers was a focus group interview. This interview was held at the end of October, after I finished classroom observations. I asked the professional developers to watch video clips of classroom teaching by each teacher participant. Then, I asked them to reflect on those clips. The aim of this interview was to investigate the professional developers' reaction to the teachers' implementation in their classroom subsequent to the PD.

Teacher interviews. I conducted three interviews with teacher participants. The aims of the interviews were to investigate teachers' orientation about science teaching, and knowledge and beliefs about students, instructional strategies, curriculum, and assessment. I had planned to do the first teacher interview (Appendix F) and card sort

activity (as shown in Table 5) at the PD, while sessions were running. However, because of the schedule, there was not enough to conduct the interview. Instead, I had to arrange the interviews to take place in the evening after the PD sessions. I conducted the second interview and card sort activity with teachers in the two weeks following the PD. I met with each teacher individually and conducted the interview at her school. This interview focused on the investigation of teachers' orientation to science teaching, and knowledge and beliefs about students, instructional strategies, curriculum, and assessment. In addition, I also focused on their plan of implementing PD units to their classroom.

The third interview was conducted in October 2006, after the teachers taught the PD units. I made an appointment with teachers to conduct the interview and card sort activity with them. Inspired by Seidman (1991), the questions in this phase of the interview series addressed the intellectual and emotional connections between the participants' work and life. Thus, the questions in this interview focused on their knowledge, the implementation of the units from the PD, and the meaning of teaching a particular science topic. Each interview lasted up to 90 minutes to allow the participants to recall, reconstruct, and reflect on their experiences.

All the interviews and card sort activity with professional developers and teachers were audio-taped. I transcribed the professional developers' and teachers' interview for analysis. I did not transcribe the card sort activity, but revisited the tapes to the details of the participant responses.

Card-Sorting Task

The card-sorting task was originally designed as a research tool for eliciting teachers' purposes and goals for teaching science to a particular group of students

(Friedrichsen & Dana, 2003). More important than how the teachers sort particular cards, the card-sorting task allows the researcher to hear what participants say during the sorting that offers the most insight into their science teaching orientation. This task helps the participants to clarify what they believe about teaching and learning science.

Professional developer card sort activity. I designed card sorts for the professional developers. I used the card-sorting activity as a primary data source to elicit the professional developers' orientations to PD. I designed a set of 15 scenarios for the card-sorting task (as shown in Table 5) that would elicit participants' knowledge and beliefs about PD. I developed scenarios for professional developers based on the science orientations offered in Magnusson et al. (1990) and used the scenarios in Friedrichsen & Dana (2003) as a guideline. Then, I asked experts to comment on the validity of the PD cards.

Table 5

Representative Sample of Card Scenarios for Professional Developers

Item	Scenario	Orientation
1.	You, as a professional developer, begin a unit of dissolution by asking students to draw a picture of sugar when putting into water. You facilitate discussion among teachers.	conceptual change
2.	You, as a professional developer, begin a unit of electricity by having teachers talk about their ideas about electricity. Then you allow teachers to work with a particular circuit and develop their own explanations. You show the scientists' ideas about electricity and encourage teachers to discuss and compare how their ideas are different to the scientists.	conceptual change
3.	You, as a professional developer, set up PD lessons for a unit on heat conduction. You introduce heat conduction activities for a 6 th grade elementary book. You select a variety of fun, and easy-to-do activities for PD.	activity-driven
4.	When doing laboratory activities, you provide teachers with clear, easy following, step-by-step directions for the activity procedure. Every activity was in the National Curriculum. You also provide the teachers with materials to help them implement the activities at their classrooms.	activity-driven

Table 5 (continued)

Item	Scenario	Orientation
5.	You, as a professional developer, engage teachers in discussion about how they are going to teach a sound unit to 5 th grade students. You encourage teachers to work in group to discuss and develop a 1-week lesson plan of this unit.	problem-based learning
6.	You, as a professional developer, encourage the teachers to place an ice brick on their table. You encourage the teachers to carefully and accurately record their observations in a journal.	process-driven
7.	As a professional developer, you want teachers to learn about how sound is produced. You decide the best way to do this is to demonstrate with various musical instruments to verify a science concept of vibration produces sound.	academic rigor
8.	You, as a professional developer, design a PD lesson on dissolution by encouraging teachers to do activities that their students would do. At the end of session, you assign teachers to discuss within their group, then as a whole about what they learn about dissolution and about teaching this unit.	reflective
9.	You, as a professional developer, begin a unit on sound by introducing curriculum, explaining materials, allowing teachers doing activities, and you explaining the concepts at the end of activities.	didactic
10.	You, as a professional developer, have teachers first engage in laboratory activities in a book, class discussion. You will end each activity with your explanation of science knowledge beyond those activities.	didactic
11.	Teachers are intrigued with a Thai flute that a classmate has brought to school. As a group, the teachers identify questions and ways to explore how the flute works. You help the teachers organize into investigation teams, and you investigate along with the teachers.	guided inquiry
12.	Teachers have just completed a simple circuit with multiple bulbs. For the next unit on electricity, you ask the teachers to make the bulbs light using a combination of wire, bulbs, and switch.	guided inquiry
13.	You, as a professional developer, have teachers observe a music instrument and generate questions about how sound is produced. Each group designs and carries out their own experiment to test a hypothesis related to the group's questions.	Inquiry
14.	You, as a professional developer, set up a variety of materials at a back of room for teachers to investigate about sound has different properties such as pitch, volume, and timbre.	Inquiry
15.	As a professional developer, you begin a unit of heat conduction by engaging in activities that you hope the teachers will use with their students. You demonstrate teachers to use whiteboarding and cooperative learning in teaching those activities.	Pedagogy-driven

I conducted the card sort activity with professional developer participants two times. I performed this task within the first interview with the professional developers

about the PD design process. I asked participants to sort the cards based on whether or not the scenario was representative of their PD instruction. Throughout the card sort activity, I encouraged the professional developers to talk about their PD instruction, especially in regards to how their teaching strategies were similar to or different from those described on the cards. After they sorted and selected representative scenario cards, I asked each professional developer to put the cards into three groups, “like me,” “not like me,” and “can’t decide”. After the professional developer grouped all of the cards, I asked him/her to arrange the cards in the “like me” group, ranging from most like them to least like them. I asked professional developers to do the same thing with the cards in the “not like me” group. While the participants were sorting the cards, I encouraged them to describe how the selected scenarios supported their purposes and goals for PD. During the card-sorting task, I took field notes of participant’s reaction when reading scenarios, and his/her pace of sorting each card. I also audiotaped the participant’s thought they made oral comments after reading each scenario. The card sort activity lasted up to 60 minutes for each participant.

During the second interview, I conducted the card sort activity a second time. I asked each professional developer to revisit all the cards then asked him/her to review each card and asked if he/she wanted to arrange the order or group of any cards. Then, I selected certain card scenarios for them to reflect on how the strategies in the scenarios were similar to or different from their PD strategies. I allowed the interviewees to change the scenarios in ways that would more closely fit their teaching strategy. I recorded the participants while they were sorted and reflected on each card scenario. The recorded of participants’ comments on the cards allowed me to revisit the data again during the

analysis process in order to get insight on the professional developer participants' orientations about PD. The second card sort activity lasted up to 30 minutes for each professional developer.

Teacher participant card sort activity. I developed another set of card-sorting scenarios (as shown in Table 6) for the participating teachers to investigate their orientations in science teaching. Each card scenario for the teachers was parallel to the card scenario for the professional developers. I performed the card-sorting task with the teachers three times in order to explore how the PD helps them to develop their orientations in science teaching. I conducted the card sort activity at the same time as the interviews. The first card-sorting task was at the beginning of PD, the second one was right after the PD, and the last one was after PD unit implementation. Similar to the professional developers, I encouraged teacher participants to talk about their teaching and how their teaching strategies were similar to or different from those described on the cards. After the teachers sorted and selected representative scenario cards, I asked them to describe how the selected scenarios supported their purposes and goals for teaching a particular topic. Because of the time constraint and the fact that teachers were exhausted from the PD sessions, the first card sort activity did not seem to work. Unlike the professional developers, the teachers hurried to group the cards and did not give details about their thinking and reflections. Thus, I did not ask teachers whether or not they liked or did not like each scenario.

Two weeks after PD, I conducted the second card sort activity with the second interview at the participants' schools. I asked each teacher to revisit all the cards that she had sorted and then asked her to review each card again. I asked each teacher participant

to put the cards into three groups: “like me,” “not like me,” and “can’t decide”. After the teacher grouped all cards, I asked her to arrange the cards in “like me” group from most like her to least. I asked them to do the same thing with the cards in the “not like me group.” During the sorting, I encouraged the teachers to describe how the selected scenarios supported their purposes and goals for teaching science. During the card-sorting task, I took field notes of participants’ reactions when they read the scenarios, and their pace in sorting each card. I audiotaped the participants’ thinking aloud after they read each scenario. The second card sort activity lasted up to 50 minutes for each participant.

The third card sort task occurred after my classroom observation had ended. I asked each teacher to revisit the cards and allowed her to reconsider whether she wanted to rearrange the groups or order. Then, I selected some card scenarios for the teacher to reflect on regarding how the scenario represented or did not represent her teaching. I also allowed the teacher to change the scenarios in ways that would better match her teaching strategy. I took field notes and recorded the participants during the sorting and reflecting. The third card sort activity lasted up to an average of 40 minutes per participant.

Table 6

Representative Sample of Card Scenarios for Teacher Participants

Item	Scenario	Orientation
1.	You, as a teacher, begin a unit of dissolution by asking students to draw a picture of sugar when putting into water. You facilitate discussion among students.	conceptual change
2.	You, as a teacher, begin a unit of electricity by having students talk about their ideas about electricity. Then you allow students to work with a particular circuit and develop their own explanations. You show the scientists’ ideas about electricity, encourage a class to discuss and compare how their ideas are different to the scientists.	conceptual change
3.	You, as a teacher, set up classroom lessons for a unit on heat conduction. Using resource elementary books, you select a variety of fun, and easy-to-do activities.	activity-driven

Table 6 (continued)

Item	Scenario	Orientation
4.	When doing laboratory activities, you provide students with clear, easy following, step-by-step directions for the activity procedure.	activity-driven
5.	In an electricity unit, you, as a teacher, give students batteries, bulbs and wires. You encourage the students to find all the possible ways to light the bulb.	discovery
6.	You, as a teacher, have students observe two phenomena, salt in water and ice in water, and generate questions about their changes. Each group designs and carries out their own experiment to test a hypothesis related to the group's questions.	discovery
7.	You, as a teacher, encourage the students to place an ice brick on their table. You encourage the students to carefully and accurately record their observations in a journal.	process-driven
8.	As a teacher, you want teachers to learn about how sound is produced. You decide the best way to do this is to demonstrate students with various activities to verify a science concept of vibration produces sound.	academic rigor
9.	You, as a teacher, design a science unit around the question, "What's in our drinking water?"	project-based science
10.	You, as a teacher, want students to learn the heat conduction. You decide to ask your students to observe and record about the material used for cooking utensil. Then you and students design an activity around the question, "What are the best materials in making cooking utensils.	project-based science
11.	You, as a teacher, begin a unit on Sound by introducing curriculum, explaining materials, allowing students doing activities, and you explaining the concepts at the end of activities.	didactic
12.	You, as a teacher, have your students first engage in laboratory activities in a book, class discussion. You will end each activity with your explanation of science knowledge beyond those activities.	didactic
13.	Your students are intrigued with a Thai flute that a classmate has brought to school. As a group, the students identify questions and ways to explore how the flute works. You help the students organize into investigation teams, and you investigate along with the students.	guided inquiry
14.	Your students have just completed a simple circuit with multiple bulbs. For the next unit on electricity, you ask the students to make the bulbs light using a combination of wire, bulbs, and switch.	guided inquiry
15.	You, as a teacher, have students observe a music instrument and generate questions about how sound is produced. Each group designs and carries out their own experiment to test a hypothesis related to the group's questions.	inquiry
16.	You, as a teacher, set up a variety of materials at a back of room for teachers to investigate about sound has different properties such as pitch, volume, and timbre.	inquiry

Observations

Observations used in conjunction with interviews provide ways to explore participants' actions more deeply (Hatch, 2002). The goal of observation is to understand the culture, setting, or social phenomenon. Direct observation is a primary source in a case study in order to gather the evidence of relevant behaviors (Yin, 2003). Hatch (2002) suggested five strengths of observational data for qualitative research: (1) permit better understanding of the contexts that phenomena occurs, (2) discover how the participants understand the setting, (3) bring out hidden things from interview to the surface, (4) learn sensitive information, and (5) add to researcher's experience to analyze the phenomena. My observations took place in two phases; the first phase was during the PD, and the second phase was in school classrooms.

PD observation. This PD project was a 3-day project held in August, 2006, which I observed in its entirety. There were 131 teachers who participated in this PD project. The professional developers divided the teachers to two groups (as shown in Figure 4). Each group attended all seven sessions: 2 physics sessions, 1 biology session, 1 chemistry session, 2 earth science sessions, and 1 session about material development. A session on assessment and evaluation was also planned for the afternoon of the third day. However, this session was canceled at the last minute. Instead, a closing ceremony which awarded certificates to PD participants was shifted to replace the cancelled session.

On the first day of PD, I observed Piti and Vimom teaching sound and electricity units to teachers in group I. There was an opening ceremony at the beginning of first day of PD. This ceremony lasted to an hour. The sound and electricity session ran only two hours, which was the shortest of the PD sessions. The rest of PD sessions lasted about 3

hours. In the morning of the second day, I observed Piti and Vimon teaching sound and electricity units again, but to teachers in group II. In the afternoon of the second day, I observed Sommit teaching chemistry sections to teacher in group I. On the third day of PD, I observed Somsri teaching chemistry units to teachers in group II (All teacher participants were in group II).

My observations during the PD implementation focused on the four professional developers as they taught their sessions and on the four teachers as they participated in PD activities, including the instances when they collaborated with their peers. During all observations, I took field notes and videotaped the events for the purpose of stimulated recall and further analysis. The professional developers' answers in the first interviews drove my observations of PD. During PD observations, I focused on (1) how the professional developers' knowledge and beliefs were integrated in action; (2) how the professional developers modeled reformed-teaching in science based on Thai educational reform; (3) differences between PD planning and implementation; (4) how the professional developers promoted teachers' learning during the PD; and (5) how the teachers constructed knowledge within the PD context. After the observations, the stimulated recall helped me to probe the professional developers' knowledge and beliefs about how teachers learn and how this particular PD helped teachers learn.

Classroom observation. My observation of each teacher's teaching in the classroom took place from August to October. As with the professional developers, my observation of each teacher participant's teaching was driven by their answers on the first and second interviews. My observations focused on the teachers' integration of knowledge from the PD into classroom teaching, and if the teachers adopted any

reformed-teaching from the PD to their classroom. After I had received permission from school principals to allow me to collect data with the teachers at schools, I set an observation schedule with each teacher about their teaching plans, and implementation. For the 10 weeks of my observation period, I set up and arranged a daily schedule among Manee, Chujai, Jinda, and Wanna to observe their science teaching. They did not teach the same period of time. Because some of their science classes overlapped, so I asked them to rearrange their teaching schedule so that my observations were possible. During observations with each teacher participant, I took field notes. I videotaped Manee, Chujai, and Jinda's when they taught science, but only took field notes when I observed Wanna in her classroom.

Documents and Records

Documents and records are useful sources of information (Lincoln & Guba, 1985). In light of this, I reviewed IPST program artifacts, which included the proposal for the professional development project, for the purpose of documenting issues such as the goals of the program, the intended pedagogies, duration of the program. In addition, I collected worksheets that the teacher participants created for their students after they returned to their classrooms. These artifacts were secondary sources for the purpose of understanding the teachers' knowledge and practice.

Data Analysis

Data analysis is the interplay between researchers and data. A case study is an exploration of a bounded system or a case over time through detailed, in-depth data collection involving multiple sources of information that is rich in context. In this research, I used grounded theory technique (Strauss & Corbin, 1998) to develop an

understanding of the case. Grounded theories are likely to offer insight, enhance understanding, and provide a meaningful guide to action. Theory that emerges from data is more likely to resemble the reality of the case being studied than is theory derived by putting together a series of concepts based on experience or speculation (Strauss & Corbin, 1998). The primary data sources were field notes from observations, interview transcripts, and responses to the card-sorting activities. Artifacts, such as PD handbook or PD activity manual served as a secondary data source (Appendix G). I began analysis as soon as data become available and continued through out the research process.

After interviewing the professional developer and teacher participants, I transcribed all audio-taped interviews verbatim in Thai and then reviewed each interview transcript for accuracy. The next step in the data analysis was to code the interview and card sort transcripts in order to look for orientations and PCK for PD of the professional developers. I applied an open coding process which categorized data from the interview transcripts, observation field notes, and discourse transcripts from card-sorting into discrete parts that I could then examine closely against the professional developers' teaching practice. I started coding the interview transcripts with professional developers for comments related to professional developers' orientations to PD, knowledge and beliefs about teachers, curriculum, strategies, and assessment for PD. I also looked for other factors that the professional developers took into account during the PD design process. I generated initial categories from comments in the interview transcripts that were conceptually similar or related in meaning to the professional developers' orientations, knowledge, and practice. According to this coding process, I developed the categories using the research theoretical framework as a guideline in order to examine

professional developers' orientation and PCK for PD. I developed definitions of the categories, and then revisited the professional developers' interview transcripts. The rereading and recoding processes occurred over several rounds until the generated categories were saturated. I performed open coding of the interview transcripts and observation field notes in order to examine the professional developers' practice during the PD implementation. I recoded the interview and card sort transcripts, and observation field notes in order to support or refute the initial categories I had generated. I then developed explanations of themes and looked for patterns. I performed axial coding (Strauss & Corbin, 1998) in order to look for cues about how major categories related to each other.

Observation field notes also served as a primary data source for my analysis. I analyzed the field notes in order to understand the instructional practices of professional developers. In addition to the analysis of field notes of observations, I reviewed all videotapes of PD lessons to confirm the notes that I made. According to the PD implementation clips, I developed teaching descriptions of each professional developer that represented the typical PD implementation. In addition, the reviewing of video tapes allowed me to look at specific events within the lessons that were taught such as, how the orientations related to PD implementation. Throughout the descriptions of the professional developers, I also analyzed the documents and artifacts that I collected from PD, such as handbook and activity manual.

The comments and reflections of participants on the card sort activity served as a primary data source for my analysis in order to explore the orientations of participants. In an analysis of the card-sorting task, the end result of selecting a particular set of cards is

not particularly insightful; rather, it is the discourse that occurs during the sorting process that offers insight into the participant's science teaching orientation (Friedrichsen & Dana, 2003). I transcribed the card-sorting audiotapes and I revisited the audiotapes to gather details about professional developers' orientations. I developed initial categories while listening to the audiotapes. The categories I generated mainly relied on the orientations that proposed by Magnusson et al. (Magnusson, Krajcik, & Borko, 1999). In this study, I defined orientation to professional development as knowledge of the importance and goals of PD to a particular group of teachers. It also refers to the knowledge of the purposes for PD for a particular group of teachers or the *overarching conceptions* of PD for a particular group. According to Magnusson et al. (1999), there are nine orientations to science teaching: process, academic rigor, didactic, conceptual change, activity-driven, discovery, project-based science, inquiry, and guided-inquiry. In this study, I modified these orientations to science teaching and applied them to orientations to PD. In addition to the nine orientations by Magnusson et al. (1999), pedagogy-driven orientation was a new orientation to PD that I developed during the analysis process. These 10 orientations are explained as follow:

Process – the professional developer introduces teachers to the thinking processes employed by scientists to acquire new knowledge. They engage teachers in activities to develop thinking process and integrated thinking skills.

Academic Rigor – the professional developer challenge teachers with difficult problems and activities. Laboratory work and demonstrations are used to verify science concepts.

Didactic – the professional developer presents information, generally through lecture or discussion and questions directed to teachers are to hold them accountable for knowing the facts produced by science.

Conceptual Change – teachers are pressed for their views about the world and consider the adequacy of alternative explanations. The professional developer facilitates discussion and debate necessary to establish valid knowledge claims.

Activity-driven - teachers participate in “hands-on” activities used for verification or discovery. The chosen activities may not be conceptually coherent if teachers do not understand the purpose of particular activities and as consequence omit or inappropriately modify critical aspects of them.

Discovery - teachers explore the natural world following their own interests and discover patterns of how the world works during their explorations.

Project-Based Science – professional developer and teacher activity centers around a “driving” question that organizes concepts and principles and drives activities within a topic of study. Through investigation, teachers develop a series of artifacts (products) that reflect their emerging understandings.

Inquiry – professional developer supports teachers in defining and investigating problems, drawing conclusions, and assessing the validity of knowledge from their conclusions.

Guided Inquiry – professional developer and teachers participated in defining and investigating problems, determining patterns, inventing and testing explanations, and evaluating the utility and validity of their data and the adequacy of their conclusions. The

professional developer scaffolds teachers' efforts to use the material and intellectual tools of science, toward their independent use of them.

Pedagogy-Driven – Teachers were encouraged in a learning environment that aims to introduce pedagogical knowledge and PCK that are necessary in science teaching. The professional developer presents information through lecture, activity, discussion and questions in order to develop an awareness of science teaching among teachers. The chosen PD activities may or may not be selected to enhance content knowledge for teachers.

Based on the meaning of orientations toward teaching science by Magnusson et al. (1999), I defined orientations toward PD as professional developers' knowledge and beliefs about the purposes and goals for providing PD to a particular group of teachers. I used both central and peripheral components to represent the professional developers' orientations. I defined central components as goals that dominated the professional developer participants' thinking and appeared to drive the instructional decision-making process. These goals were highly visible during PD planning, PD implementation, and interviewed. The central goal of the majority of professional developers was to provide activities that work (Appleton, 2005) to the teachers. They saw themselves as having a role in exposing the PD teachers to the information about the National Science Curriculum and helping them become aware of how to do and manage those activities in their classroom. The professional developer participants also showed peripheral goals, which I defined as secondary goals that slightly influence to decision-making.

As the next step in the analysis process, I developed an orientation map for each professional developer based on the data that I analyzed from interviews, observations,

and card sort activities. The orientation map guided me to develop claims and assertions that answered the research questions. In the orientation map, each box, oval, line and arrow was supported by the evidence from interview transcripts, observation field notes, and card sorting transcripts.

For the analysis of teachers' data, I repeated the same analysis steps with the interview transcripts. I coded those transcripts in order to look for comments related to teacher participants' orientations to science teaching, knowledge and beliefs about students, curriculum, strategy, and assessment for science teaching. During the coding process, I developed categories and subcategories. Then, I generated definitions for each category and subcategory that I had developed. Again, I reread and recoded the teacher interview transcripts for several rounds until the categories were saturated.

For the card sort activity, I transcribed the card-sorting audiotapes and revisited the audiotapes to gather details about teachers' orientations to science teaching. I developed initial categories while listening to the audiotapes. Similar to the analysis of the card sort with professional developer, the categories I generated mainly relied on the 9 orientations toward science teaching proposed by Magnusson et al. (1999). I compared these categories to the categories that I generated from the interview transcripts and looked for the emerging themes and the relations among categories. I developed claims based on these themes.

I analyzed the observation field notes that I took during classroom observations in order to understand the instructional practices of teachers. In addition to the analysis of field notes of observation, I reviewed all videotapes of classroom teaching in order to confirm the field notes and develop teaching descriptions for each teacher that

represented their typical teaching practice. In addition, the reviewing of video tapes allowed me to look at specific events within the lessons that were taught such as, how the orientations related to the instruction. Throughout the descriptions of the teachers, I also analyzed the documents and artifacts that I collected from classrooms, such as students' works.

I developed an orientation map for each teacher participant that later guided me to develop the assertions in response to the research questions. I created the orientation map based on the data for teachers that I analyzed from interviews, card sort activities, and observations.

To support my claims with evidence during the writing process, I translated the relevant interview transcripts and card-sort portions to English in order to communicate with my committee members and non-Thai readers about the data. However, the translations reflect more of the important and meaningful ideas rather than a verbatim translation of the Thai language, which may otherwise result in the loss of meaning during translation.

Example:

Thai:

เขาไม่ได้สนใจเลยว่าคุณทำอะไรมาเขาสนใจแต่ทำอะไรเป็นอะไรเพราะอะไร คือคุณต้องท่องให้ได้นะ คุณต้องจำให้ได้นะคือเน้นเนื้อหามากเกินไปกลายเป็นว่าเลยเป็นวิทย เป็นเรื่องที่ยิ่งไกลเกินตัวเขาเข้าไปใหญ่มันจับต้องไม่ได้มันไม่ได้มองเห็น มันมีแต่จำ

Verbatim Translation:

They are not care what labs you did. They only care what is what and why. You must read and remember. It emphasizes on content too much so science is too far to them. It is too big, untouchable, cannot see, and better to remember.

Meaningful Translation:

Nobody cares how good at lab performance you are, they care about how much content you know, or memorize. Yet, for students, science is too hard to understand, but it is easier to memorize instead.

Because I worked at IPST for several years before I started my Ph.D. program. I was familiar with the professional developers and also IPST's mission as it related to providing professional development for teachers across the country. Thus, during the analysis process, I debriefed with my advisor and peers in the Science Education program to ensure that my assertions were supported with data I collected, as opposed to being based on my prior knowledge. The discussion with these individuals also helped me to ensure that the assertions I made were aligned with the research questions.

Trustworthiness

The naturalistic criteria for trustworthiness are credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985, p. 219). Triangulation and peer debriefing can establish credibility; thick description can facilitate transferability; auditing can establish dependability and confirmability.

In regard to credibility, I triangulated of data by collecting data from several different sources: interview, direct observation, card-sorting task, and documents and records revision. Credibility was also established through peer debriefing. According to Lincoln and Guba, the purpose of peer briefing is to (1) help the researcher to keep honest to the research questions, (2) provide opportunities to test working hypotheses, (3) allow to develop initially and test next steps in the emerging methodological design, and (4) provide the researcher with an opportunity for catharsis. In this research, I discussed my analysis with my peers in the Science Education program to ensure that my claims aligned with my research questions and to achieve these four purposes of the peer briefing technique.

To establish transferability, I provided the thick description necessary, such as time and contexts. This thick description helps the readers to understand how the findings are transferable to other situations.

In regard to dependability and confirmability, I asked my advisor and committee members to play the role of external auditors to check on steps taken in relation to credibility. This included the appropriateness of my inquiry decisions and methodology, and ascertaining whether the findings were grounded in the data by tracing back through transcripts. I also asked them to examine whether inferences based on the data were logical, looking carefully at analytic techniques used, appropriateness of category labels, quality of interpretations, and the utility of categories.

CHAPTER FOUR: FINDINGS ABOUT PROFESSIONAL DEVELOPERS' KNOWLEDGE, ORIENTATIONS, AND PRACTICES

The research questions guided the findings of this study. I organize this chapter by beginning with the discussion of the characteristics of the PD project in this study. I also discuss the description of the implementation in PD of each professional developers, Sommit, Piti, Somsri, and Vimon. Then, I discuss the assertions that I developed from data to address the research questions about professional developers' orientations, knowledge, and practice in professional development.

Characteristics of the PD Project

This PD project was a 3-day project that was provided for private school teachers across Thailand. The PD program and schedule was set by the professional developers based on the primary science textbook. The sessions were organized in a parallel format (see Figure 5). The PD participants were required participate in every session, including Sound and Electricity, Light, Force and Movement, Biology, Chemistry, Earth and Space Science, Sky Map Application, Instructional Material Development, and Assessment. All the manipulatives used for the PD activities were supported by the Kurusapa Business Organization (KBO), under the Ministry of Education. In addition, staff members at the KBO also assisted the professional developers in preparing and distributing out the materials to the teachers during the PD sessions.

According to Figure 7, each PD session was generally lasted 4 hours, except two sessions that were on the first day of PD, Sound and Electricity and Biology, because there were registration and ceremony events prior these sessions.

Figure 7. Professional Development Schedule

	8-8.30	8.30-9	9-12	12-1	1-2.30	2.45-4	7-9
Aug 7	Registration	Opening Ceremony	PD Session: Sound & Electricity	LUNCH BREAK	PD Session: Biology		Instructional Material Development
			PD Session: Biology		PD Session: Light, Force, & Motion	Sky Map Application	
Aug 8	PD Session: Light, Force, & Motion		PD Session: Chemistry		Sky Map Application		
	PD Session: Sound & Electricity		PD Session: Earth and Space Science		Instructional Material Development		
Aug 9	PD Session: Earth and Space Science		PD Session: Assessment of Student Learning		Closing Ceremony		
	PD Session: Chemistry						

-  PD Participants in Group One
-  PD Participants in Group Two
-  All PD Participants

At the registration, the participants received a package which included a *PD handbook*, *Misconception in Elementary Science* book, and *Science Education Standards*. However, the professional developers only used the PD handbook during PD implementation and did not walk teachers through the other two books that were included in the package. The *Misconception in Elementary Science* book, in contrast to its title, (see Appendix H) provided content knowledge in the areas of science, such as chemistry, biology, and physics rather than misconceptions or learning difficulties that teachers or students might have in the science classroom. The PD handbook had 470 pages included (1) goals of science teaching, (2) pedagogy in teaching science, and (3) activity manual. The activity manual included key concept of the activity, expected learning outcomes, activity time duration, activity directions, materials, suggestions, content knowledge for teachers, content knowledge for students, and examples of observation worksheets with activity results. However, these components were not consistent among the PD sessions. For example, the activity manual for the chemistry session did not provide answers and activity results, while the manual of physics sessions provided the answers and results of activities.

According to the pedagogy for teaching science discussed in PD handbook, the PD defined inquiry as

Inquiry คือกระบวนการสืบเสาะหาความรู้ที่ช่วยให้ผู้เรียนเกิดการเรียนรู้ทั้งเนื้อหาหลักและหลักการ ทฤษฎี ตลอดจนการลงมือปฏิบัติ เพื่อให้ได้ความรู้ซึ่งเป็นพื้นฐานในการเรียนรู้ต่อไป

Inquiry is an investigation process that helps learners to develop content knowledge, concepts, theories, and hands-on experience, which are the fundamental knowledge in further science education (PD handbook, p. 4)

Furthermore, the PD manual also presented an *Inquiry Cycle* as shown in Figure 8, consisting 5 steps including (1) engagement, (2) exploration, (3) explanation, (4) elaboration, and (5) evaluation.

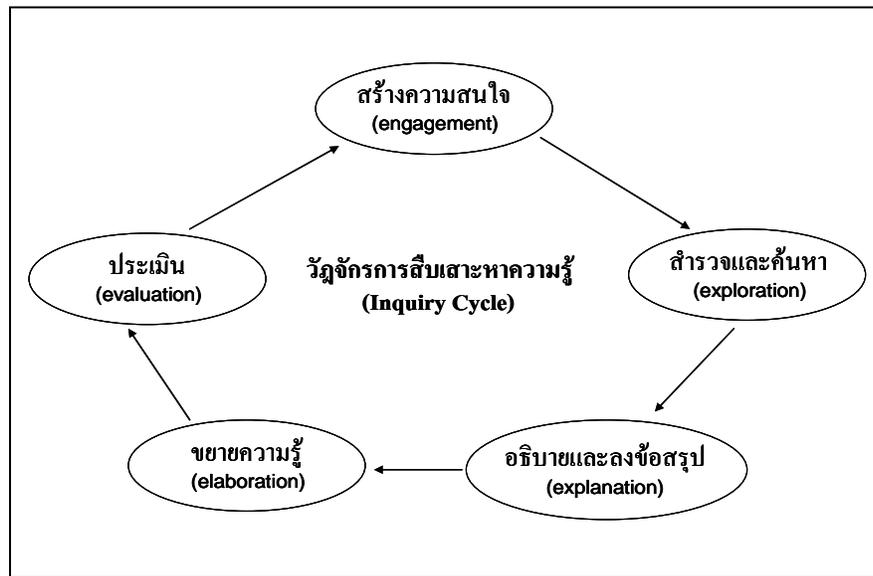


Figure 8. Inquiry Cycle

During the PD implementation, the professional developers chose to use the 5 steps in the Inquiry Cycle to varying degrees as the PD strategy. In addition, some professional developers also attempted to help teachers understand this teaching model and implement it in their classroom.

There were 133 teachers who participated in this PD; the first 66 teachers on the list were grouped as Group One, and the remaining teachers were grouped as Group Two. According to Figure 5, after the opening ceremony the PD participants in Group One relocated to the Sound and Electricity session while the Group Two participants relocated to the Biology session. In regards to this research, I observed two PD sessions --Sound and Electricity and Chemistry sessions-- for the entire PD project.

In the Sound and Electricity session, there were 10 groups of 6-7 teachers. The teachers independently decided what group he/she wanted to sit. In general, the members of group did not change for the entire PD project, and the teachers from the same school preferred to sit together. There were six activities in the Sound unit and some activities were divided to small parts. The six activities were:

- (1) How Sound is Produced – to introduce the key idea that sound is produced by vibration of the sources.
- (2) How Sound Moves – to introduce the key idea that energy from vibrations moves to every direction from the sources.
- (3) Sound Travels through Media – to introduce the key concept that sound travels through solids, liquids and gases.
- (4) How We Hear Sound Differently - to introduce the key concept that frequency
- (5) Pitch - to introduce the key concept that high pitch sounds are caused by more vibrations and low pitched sounds are caused by fewer vibrations.
- (6) Energy and Loudness - to introduce the key concept that at the same frequency more energy causes louder sound.

The PD time for Sound unit lasted one hour. The teachers were engaged in doing activities two and five because goal of the professional developer, Piti, focused on modeling of pedagogy in teaching science rather than introducing activities or content knowledge. Thus, Piti chose the activities that modeled the 5E model of instruction to the teachers.

In the Magnetism and Electricity unit, there were six activities and some activities were divided to small parts. The six activities were:

- (1) Magnet - to introduce key ideas on how magnets work.
- (2) Electrostatic - to introduce key ideas on how the charging of various objects causes repelling and attraction forces.
- (3) Property of Electricity Conductor and Insulator - to introduce key ideas on how currents can flow through conductor, but cannot flow through insulator.
- (4) Simple Circuit - to introduce key ideas on components of simple circuit.
- (5) Series and Parallel Circuits - to introduce key ideas on the difference between series and parallel circuits and their effects on bulb brightness.
- (6) Electromagnets - to introduce key ideas on how a moving electron (current) generates a magnetic field around the wire.

The professional developer who took care of this unit was Vimom. She engaged teachers in both groups to do all six hands-on activities. Teachers in Group One had only two hours for this unit while teachers in Group Two had three hours.

In the Chemistry session, the organization of groups was similar to the Sound and Electricity session, and teachers sit in the same groups. There were two professional developers who took care of this session, Somsri and Sommit. While Piti and Vimom shared the topics to teach, Somsri and Sommit decided to share the session differently. Somsri was responsible for providing PD for teachers in Group One when Sommit was responsible for providing PD for teachers in Group Two. Similar to the Sound and

Electricity units, the Chemistry unit was comprised six activities, with each activity divided into small parts. These activities included:

- (1) Materials - to introduce key ideas on how some objects are made from one material while some objects are made from many materials.
- (2) Properties of Materials - to introduce the key idea that each material has different properties.
- (3) Matter - to introduce key ideas on components of matter
- (4) States of Matter - to introduce key ideas on properties of solid, liquid, and gas.
- (5) Change of Matter - to introduce key ideas of change of state of matter, dissolution, and chemical change.
- (6) Separation Techniques - to introduce key ideas on different techniques, such as filtration, sublimation, and evaporation, used to separate different types of mixture.

The PD teachers in both groups were encouraged to participate in all hands-on activities. However, Somsri and Sommit used different strategies during the PD implementation. Somsri and Sommit started their sessions by introducing the concept map of chemistry concepts at elementary grades. Before allowing teachers to do the activities, they provided an overview of each activity to teachers. However, teachers in Somsri's session were engaged in all assigned hands-on activities step-by-step while teachers in Sommit's session did activities based on Sommit's recommendation and their own desire. The PD implementation and strategies used of Somsri and Sommit are explained in more details in the next part of this chapter.

According to the PD activities, the professional developers selected activities from the IPST Curriculum. The decision in selecting PD activities was based on personal goals for PD of each professional developer. For example, Somsri and Sommit chose the activities that were doable in terms of they fit with the session time slot. Piti selected the activities that could be modeled using the 5E model of instruction when Vimon selected activities that were fun and exciting. During the PD implementation, the PD provided opportunities for teachers to have hands-on experience. However, the PD participants still served their role as passive recipients of information and the professional developers maintained their role as knowledge and information provider.

The in-depth details about PD implementations of each professional developer are discussed in the following part of this chapter. I also discuss the individual professional developers' orientations and knowledge bases for PD.

The Individual Cases of Professional Developers' Implementation, Orientation, and Pedagogical Content Knowledge for Professional Development

Piti's Implementation, Orientation, and PCK for Professional Development

PD Implementation

During the PD, Piti started the session by engaging teachers in an activity and asked teachers to generate questions that they had about sound. He asked each group to share the questions they generated while he wrote those questions on an overhead projector. After all groups shared their questions, Piti only answered a few of them. But, for some questions, he asked the teachers to go back and find the answer themselves. He reminded teachers that in the science classroom the teachers should not immediately answer the students' questions. Instead, the teachers should encourage students to find the

answer to their questions first. After the demonstration of an engagement step, Piti asked teachers to recall what he did since the beginning of the session in order to engage teachers a sound lesson. Right after his posted question, Piti wrote “1. Engagement” on an overhead projector; then, he explained what the teachers should do to be able to engage students in the science lessons. He also provided the techniques that teachers might use with their students. After explaining the first step of 5E, Piti went back to the questions that teachers raised at the beginning. He indicated to the teachers that the students might come up with many questions, but there will only be one question that will fit the lesson that teachers planned for that day. To model the next step, exploration, Piti selected a question about how sound is produced. Piti allowed teachers to explore a selected activity on the concept that sound is produced by vibration. The teachers had about 20 minutes for exploration while Piti observed each group of teachers. After the teachers finished the activity, Piti wrote “2. Exploration” on an overhead projector and reminded teachers that they needed to allow the students to explore or do activities based on the students’ question. Piti allowed teachers to perform hands-on activities for the concept of sound is produced by vibration. Teachers were asked to fill different types of glass with water. Piti told teachers to wash their hands before rubbing at the edge of glass. After teachers finished the activity, Piti wrote “3. Explanation” on a projector and explained to the teachers that this step was for the students to play a role. He mentioned to the teachers that they should have the students formulate their explanation based on the observation or data that the students collect while doing activities. According to time restriction, Piti told teachers that he would not let teachers to do this step. Instead, he moved on the next step of the 5E model of instruction called Elaboration. Piti indicated

that the students' explanation may or may not be scientifically correct. Thus, it was the role of teachers to explain or lead the students' knowledge or explanation toward a scientific meaning. He called this process "elaboration". Then, Piti modeled the elaboration step by explaining the scientific knowledge about how sound is produced by vibration.

To teach the concept of frequency, Piti spent a few minutes explaining the concept of frequency to the teachers. However, the materials--ruler and play-do-- caused some problems. Because the session was shifted to another room, the ruler and play doe were lost for the second session. Thus, the teachers in Group One had an opportunity to do the frequency activity, but the second group of teachers did not. Although Piti indicated that the concept of sound at the elementary level was very easy for the teachers, he only spent 10 minutes to talk about this concept to the teachers, while he spent to 45 minutes on the concept that sound produced by vibration, a topic which he believed teachers would not have difficulties to learn and teach.

Piti prepared two activities that introduced the concept of frequency to teachers. Figure 9 represents the first activity that Piti showed the teachers. He told teachers to place a ruler on the table and press at the other end of ruler and see how fast the ruler would swing. Figure 10 shows the second activity that Piti introduced to teachers about the frequency concept. He asked teachers to put play-do at the end of a ruler and swing the ruler. He asked teachers to compare whether the ruler with or without a play-do swings faster.

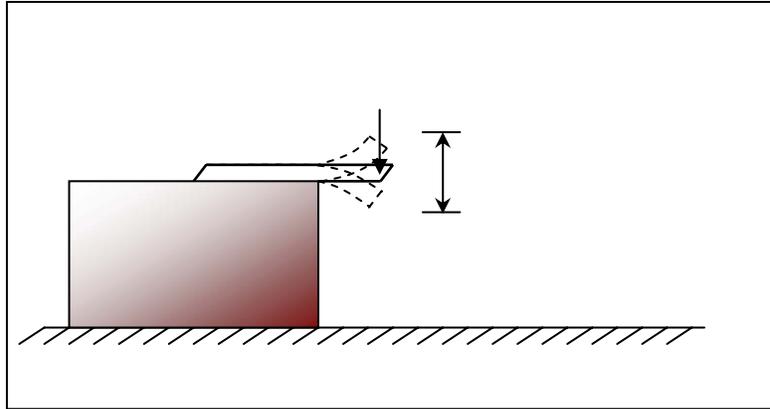


Figure 9. Professional development activity one on the frequency concept.

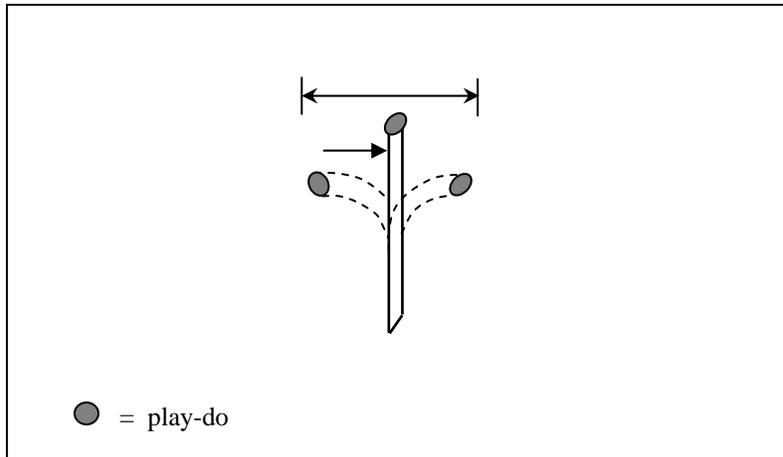


Figure 10. Professional development activity two on the frequency concept.

Although Piti provided the activities with a ruler and play-doh to teachers, he indicated that these two activities were too difficult for the teachers to understand. In addition, Piti only demonstrated these activities to teachers, but did not encourage each group of teachers to perform these activities. According to Piti, to teach this concept, the teachers should directly tell the students what frequency is and what its impacts is to human hearing.

After talking about the frequency concept, Piti returned to the overhead projector to introduce the last step of the 5E model of instruction, the evaluation. For this step, Piti

did not spend much time on it as compared to the earlier four steps. He did not model how to assess students' or teachers' learning. He only mentioned that the teachers already knew and did the formative and summative assessment in their classrooms. Piti's session lasted about an hour.

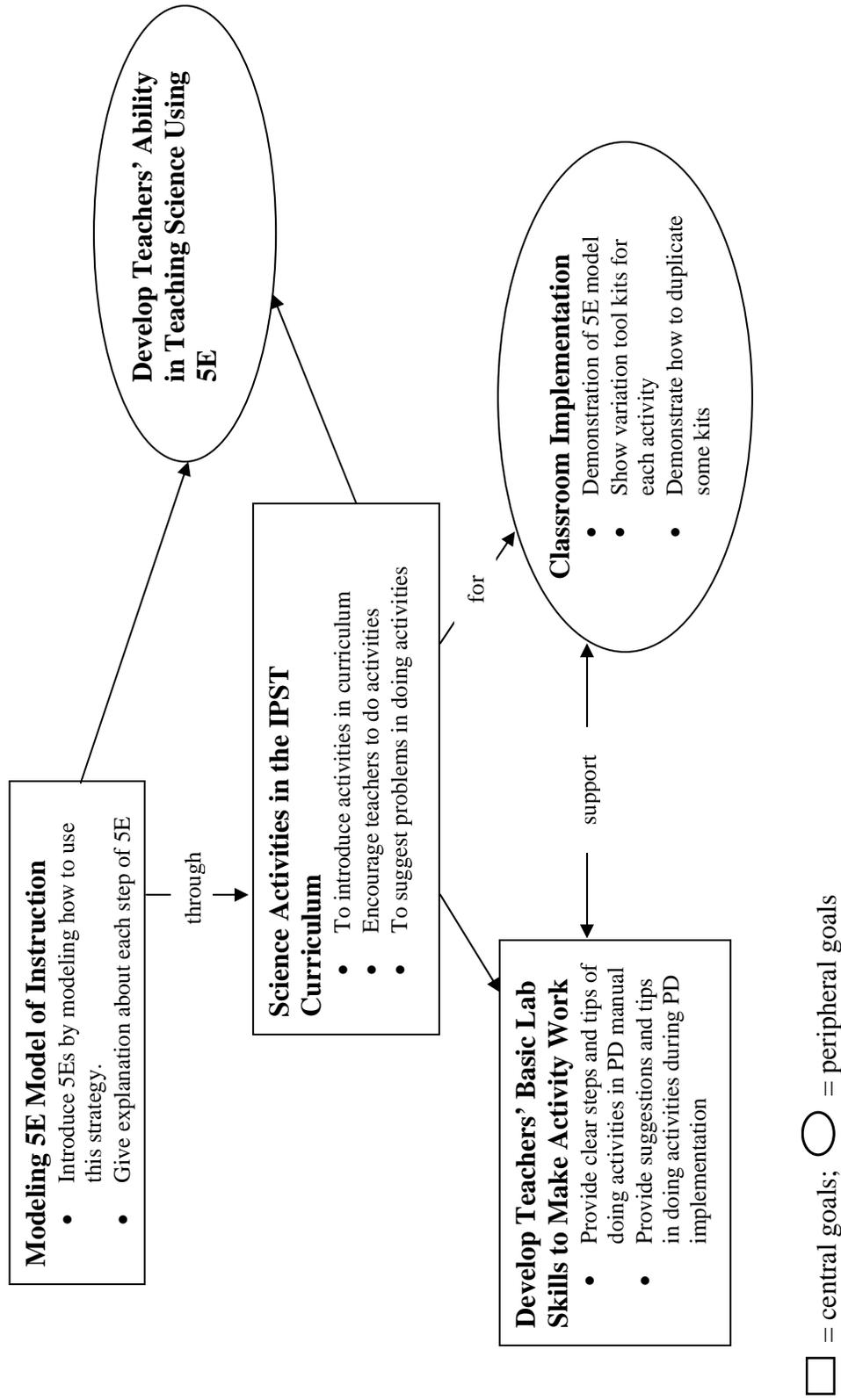
Orientation

Figure 11 represents my analysis of Piti's orientation to PD. I found that, during the interviews and PD implementation, Piti's orientations to PD consisted of 3 central goals and 2 peripheral goals. His central goals were 1) to model teaching science through inquiry; 2) to introduce scientific activities in the IPST curriculum that were aligned with the reformed National Standards; and 3) to develop PD participants' laboratory skills necessary to make each activity work. Piti clearly indicated in the first and second interviews that his goal for this PD was to model how science should be taught at schools. He did not worry that teachers lacked content knowledge on sound concept. Because, as opposed to the public school teachers, the majority of science teachers in the private schools had a science education background.

ในการอบรมครั้งนี้ตัว basic concept ของครูที่เข้าอบรมครั้งนี้ค่อนข้างดี เพราะครูเอกชนส่วนใหญ่เค้าจบมาตรงวุฒิ โรงเรียนก็พร้อมกว่าโรงเรียนของรัฐ จึงไม่มีปัญหาเรื่อง concept
As opposed to public school teachers, teacher participants in this PD had good basic concepts in science because most of them had education background in science education. (Piti, Interview #1)

He stated that the physics concepts in elementary science were not too difficult for the teachers. In addition, there were many resources that the teachers could use to find the scientific knowledge, such as science textbooks and the PD manual. Piti indicated that the current problem in teaching science at schools occurred because the teachers did not know how to teach science effectively.

Figure 11. Piti's Goals for PD



To support these goals, Piti spent most of the PD session explicitly introducing and modeling how teachers could implement the 5E model of instruction in the science classroom.

กิจกรรมที่เขาควรเห็นก็คือกิจกรรมที่จะนำไปสู่เรื่องของกระบวนการสืบเสาะหาความรู้จริงๆเราก็คิดว่าตัวเนื้อหาเขาสามารถจะหาเอาเองได้แต่สิ่งที่ต้องการให้เขาเห็นหลักๆก็คือกระบวนการเรียนการสอนว่าทำอย่างไรอันนั้นคือจุดประสงค์หลักจริงๆแล้วได้แสดงให้เห็นได้ว่าเมื่อได้คำถามแล้วเอามาทำอย่างไรจึงจะเข้าสู่กระบวนการเรียนได้ซึ่งโดยทั่วไปเท่าที่เคยดูมาไม่ค่อยได้ใช้คำถามจากเด็กโดยมากแล้วเขาจะบอกเลยว่าวันนี้จะเรียนเรื่องอะไร The activities that the teachers need to see must be the activities that lead to the inquiry process. I think the teachers could develop the content knowledge from the resource books. The most important thing for the PD is to help them have experiences that show how science should be taught. My goal is to show them how to use the students' questions into the process of teaching and learning. The teachers normally do not use the students' questions to guide the lesson, but directly tell the students what they are going to teach. (Piti, Interview #2)

Piti's goal in the PD was to model science teaching by using the 5E model of instruction rather than to develop teachers' understanding of concept on sound. Hence, Piti selected activities in which he was able to model all steps in the 5E model of instruction rather than selecting an activity that could help teachers understand a concept that most teachers had difficulties in understanding and teaching, such as the frequency concept.

อันแรก [กิจกรรม] จะให้เวลาเยอะเพราะมีเรื่องกระบวนการเรียนการสอนเข้าไปแทรกเยอะ เรามีหน้าที่ที่จะต้องเผยแพร่ออกไปโดยทำให้ดู เราพยายามทำให้ดูโดยที่ไม่ได้บอกเหมือน การบรรยายว่า inquiry 5E ต้องทำอะไรบ้าง ตรงนั้นเป็น main point ส่วนตัวหลังนี้เป็น การให้ความรู้โดยไม่แสดงวิธีสอน I spend a lot of time at the beginning of the session because I have to show teachers about the teaching techniques without telling them step-by-step and that is the main point for this PD. At the end of the session I only provide knowledge for the teacher without modeling teaching. (Piti, Interview #2)

In addition to having teachers visualize science teaching by modeling the 5E model of instruction in teaching science, Piti also asked teachers to reflect on what he had done in order to engage them to the science lessons. Piti indicated that allowing teachers to

visualize a good example of science teaching and having them have the same experiences as students were not enough. In order to help teachers develop solid understanding, the professional developers needed to provide knowledge and other important information that were necessary in teaching science.

วิทยากรควรจะให้ครูทำกิจกรรมแบบเดียวกับที่นักเรียนทำ แต่วิทยากรต้องคอยเสริมความรู้ และเน้นย้ำให้ครูตระหนักถึงบทบาทและหน้าที่ของครูในแต่ละ step ของ 5E Professional developers should have teachers to do the same activity as their students. But, professional developer have to emphasize and help the teacher be aware of their role in each step of the 5E. (Piti, Interview #1)

Hence, during the introduction of the 5E model, Piti wrote each step of this model on the transparency sheet and provided an explanation of teacher's role in each step of the 5E. He thought this would help teachers have a clear vision how the 5E model should be implemented in their classrooms. Piti also provided knowledge and tips of each step in 5E that teachers might use in their classroom. For example,

เมื่อเด็กเกิดปัญหาแล้วต้องทำอะไร ไม่ใช่ครูบอกคำตอบเลยนะ อย่างเมื่อสักครูผมตอบคำถามของอาจารย์มัย ผมบอกว่าถ้าอยากรู้ก็ต้องลองทำดู ทีนี้เมื่อเด็กมีคำถามที่เค้านสนใจ แล้วก็มาถึงขั้นสำรวจตรวจสอบ ซึ่งมันก็ไม่ใช่แค่สำรวจอย่างเดียว บางวิชาอาจใช้การสำรวจ แต่บางวิชาอย่างฟิสิกส์นี่ก็จะใช้การทดลองเป็นส่วนใหญ่ เช่นถ้าเราอยากรู้ว่าเสียงเกิดจากอะไรก็ต้องทำการทดลองเพื่อให้ได้คำตอบ แต่ถ้าทดลองไม่ได้ เช่นสอนเรื่องความร้อนบนดวงอาทิตย์มันทดลองไม่ได้เราก็ไปใช้วิธีอื่น เช่นใช้การสืบค้นข้อมูล แต่ครูมักเข้าใจว่าการสืบค้นข้อมูลคือการค้น internet อย่างเดียว จริงๆ อาจใช้วิธีสอบถามจากผู้รู้ก็ถือว่าเป็นการสืบค้นข้อมูลทั้งสิ้น

When students have questions about a phenomenon, teachers might not directly answer those questions. If you notice my teaching, did I tell you the answer? What I told you is you have to search for the answer on your own either by experimentation, or looking at the textbook. So, when students have questions, we engage them to the next step, exploration. In some areas of science, it might use only survey, but in some areas like physics most of exploration methods are experimentations. However, some concepts can't be learned by experiment such as, heat on the sun. Instead, they can do searching for information, which teachers misunderstand as searching for information only through the Internet. Actually, asking experts is also counted as searching for information, too. (Piti, During PD Implementation)

In addition to increase teachers' experience in teaching science using 5E teaching strategy by engaging them to participate in hands-on activities that were in the IPST

Curriculum, Piti indicated that teachers' experience on hands-on activities in the curriculum would lead to the possibility that teachers implemented those activities with their students in the same way that they had learned.

วิธีทำการทดลองโดยใช้การทดลองเหมือนในห้องเรียนจริงให้เขาลองทำเป็นกิจกรรมการทดลองที่เราได้เสนอแนะไว้ในหนังสือเรียนให้เขาลองทำเพื่อจะได้นำไปใช้เพราะบางคนเขาก็ไม่เคยใช้หนังสือ สสวท. เขายังไม่คุ้นเคยกับการทดลองเหล่านี้ เขาจะได้เอาไปใช้
In the PD, I will have teachers do the activities in the same way that they have to teach students in classroom. I select some activities from the IPST curriculum that they use at school. Some teachers are not familiar with the curriculum. So, they can practice then use it with their students. (Piti, Interview #1)

Another central goal of Piti was to develop teachers' basic lab skills to make activities work. During the PD implementation, Piti kept emphasizing to teachers that:

ครูต้องทำกิจกรรมให้เป็น ทำให้ถูกต้อง ไม่อย่างนั้นเอาไปสอนเด็กไม่ได้
Teachers have to know how to do the activity and do it correctly.
Otherwise, you don't know how to teach your students. (Piti, During PD Implementation)

For example, when teachers did the activity on rubbing a glass with water, Piti told teachers to wash their hands before rubbing the glass.

อาจารย์ครับทำไมผมถึงบอกให้อาจารย์ไปล้างมือก่อนทำกิจกรรมนี้ ถ้าอาจารย์ไปทำที่โรงเรียนอาจารย์ไม่ล้างมือ ที่มีอาจารย์มีโลชั่นที่ทาไว้ ทำยังไงก็ไม่ดังนะครับ
.I asked you to wash your hand before doing this activity. If you do this activity at school and you forget to wash your hands, it won't work because you put lotion on your hands before leaving home, right? (Piti, During PD Implementation)

When Piti found many teachers still could not make sound from rubbing the glass, he told teachers to touch at the handle of the glass rather than at the body of glass. He explained the reason to the teachers and warned them that they should know how to do this activity in order to help their students out of the problems when doing this activity.

According to the Figure 11, Piti's peripheral goals were 1) to develop teachers' teaching ability using the 5E model of instruction, and 2) to provide ideas and support for

the PD participants to implement activities using the 5E teaching strategy in their classrooms. I defined teachers' ability to use the 5E model of instruction and teachers' implementation of the teaching strategy and activities as peripheral goals because Piti stated these two goals during the interviews without taking any explicit action in helping teachers to meet these goals. During his PD session, Piti asked the PD participants to recall what teaching strategies he used at the beginning of the session. He also provided some suggestions to the teachers about what types of questions that they should ask or not ask students, and how the teachers should treat their students in science. Piti provided ideas of how the teachers could modify other materials for science instruction. However, Piti did not have other strategies or follow-up plans in order to help teachers develop their teaching ability in the classroom. He believed that:

อันนี้ตอบยากเพราะว่าเราไม่มีช่วงที่มีการประเมิน แต่กรณีที่เราแสดงให้เห็นดู เช่นแสดงให้ดูว่าเสียงเกิดจากการสั่นของแหล่งกำเนิดเต็มรูปแบบเขาคงเอาไปใช้ แต่อันที่เราไม่ได้แสดงให้เห็นดูเต็มรูปแบบคงไม่ค่อยได้ใช้เพราะเขายังไม่เห็นตัวอย่างว่าเวลาใช้ ใช้อย่างไร
It is difficult to say whether or not the teachers will meet my goals. But I hope teachers will implement the 5E model that they have experienced in the PD, especially, the activities that I fully modeled to them. (Piti, Interview #2)

When asked about how PD should be implemented, Piti indicated that to help the teachers understand science teaching aligned with the reform in science education, the strategies used in PD should be similar to the strategies that the teachers needed to teach in the classrooms.

เราควรให้เค้าได้เรียนเหมือนนักเรียน ให้เค้าได้รู้จักคิดเอง ทำเองก่อน ได้เสนอปัญหา รู้จักตั้งปัญหา เราจะกระตุ้นให้เค้าเกิดปัญหา จากนั้นค่อยเสนอแนะวิธีแก้ปัญหาให้เค้า
We [professional developers] should teach them the same way that they have to teach their students. We have to challenge them with the questions in order to push them thinking. We push them to have problems or problems. Then, at the end we provide the solution for them. (Piti, Card sort Activity)

During the card sort activity, Piti sorted scenario 11, 7, 8, 5, 3, and 12 as the scenarios that most represented his PD teaching. Piti’s interpretations of the six scenarios are shown in Table 7.

Table 7

Piti’s Arrangement and Interpretation of the Card-Sort Scenarios

Items	Scenarios	Piti’s Interpretations
11	Teachers are intrigued with a Thai flute that a classmate has brought to school. As a group, the teachers identify questions and ways to explore how the flute works. You help the teachers organize into investigation teams, and you investigate along with the teachers. (guided inquiry)	“I believe that I used strategies stated in this scenario during the PD. Instead of using Thai flute, I used other materials, for example, the activity to fill a glass with water and rub it or the activity about making sound with a tuning folk. I encouraged teachers to generate questions that they wanted to know about these things then had them perform activities and wrote down their observations. Teachers had an opportunity to report the findings. It was similar to this scenario.” (activity-driven)
7	As a professional developer, you want teachers to learn about how sound is produced. You decide the best way to do this is to demonstrate teachers with various musical instruments to verify a science concept of vibration produces sound. (academic rigor)	“I used demonstration techniques during the PD implementation. However, this scenario doesn’t tell what teachers have to do after the demonstration. Do they have to make their own conclusion and explanation of the demonstration? Anyway, I arranged this scenario in the second order because I also used this strategy in the PD.” (activity-driven)
8	You, as a professional developer, design a PD lesson on dissolution by encouraging teachers to do activities that their students would do. At the end of session, you assign teachers to discuss within their group, then as a whole about what they learn about dissolution and about teaching this unit. (reflective)	“We should allow teachers to have the same experience as they have to teach in the classroom. So, I agree with this scenario. In addition, the strategies used in the scenario are similar to what we used in the PD.” (activity-driven)
5	You, as a professional developer, engage teachers in discussion about how they are going to teach a sound unit to 5 th grade students. You encourage teachers to work in group to discuss and develop a 1-week lesson plan of this unit. (problem-based learning)	“We used to provide PD for teachers by teaching them how to develop lesson plan. So we did this PD before.”

Table 7 (continued)

Items	Scenarios	Piti's Reflections
3	You, as a professional developer, set up PD lessons for a unit on heat conduction. You introduce heat conduction activities for a 6 th grade elementary book. You select a variety of fun, and easy-to-do activities for PD. (activity-driven)	"I normally did not overview about the activities in the elementary book because teachers might know that already. Instead, they want to know how to use those activities in the classroom. But, I agree that the activity should be interesting to teachers so they will implement it at school." (activity-driven)
12	Teachers have just completed a simple circuit with multiple bulbs. For the next unit on electricity, you ask the teachers to make the bulbs light using a combination of wire, bulbs, and switch. (guided inquiry)	"I will use this activity for the elaboration step. Actually, the activity in the scenario isn't clear in terms of the purpose of the activity. What do want teachers to know about the function of a switch? However, I think it can be used to elaborate teachers' knowledge." (pedagogy-driven)

Table 7 reveals that Piti's orientation was likely a shift from a traditional, didactic teaching approach to an activity-driven approach. Piti preferred teachers to have experience with hands-on activities when they came to the PD. During the PD, Piti focused on using the 5E model of instruction as a PD strategy. Piti reflected on scenario 11, that he allowed teachers to generate questions from his engagement activity then selected a question for teachers to explore. He also provided an opportunity for teachers to develop their own conclusion and represent their data. Thus, although the scenario 11 was meant to represent guided-inquiry orientation, Piti's interpretation of this scenario did not align with this orientation and was more of an activity-driven orientation.

Although Piti put scenario 11 in the first order and scenario 7 second, his PD implementation strategies were closer to scenario 7 than scenario 11. Piti elaborated that:

จริงๆแล้วสถานการณ์ที่ 11 จริงๆ คืออันที่เราแสดงการเรียนการสอนนะ นั่นคืออันนี้นะ เขาตั้งคำถามเสร็จ เราให้เขาทดลอง และเขียนข้อสรุปคืออันนี้เลย ส่วนหลังจากนั้นก็ใช้การสาธิต เช่นจะเป็นกบก็ดี จะเป็นขลุ่ยเสียงนกก็ดี ป๋องแป๋งก็ดีไม่ได้ให้เขาทดลอง ใช้การสาธิตเพราะว่าบางอย่างเอามาทดลองให้ดูหมดไม่ได้ แต่ใจจริงอยากให้ครูได้ลงมือทำเอง I think I also used strategies in scenario 11. I had teachers generate questions, explore, and make conclusion and presentation. Only at the end of the session did I use demonstration techniques because there was not enough time to have teachers do every activity, which I don't really want

to demonstrate. If it is possible, I want teachers to have hands-on experience. (Piti, Interview #2)

Piti seemed to hesitate when he read scenario 7. After he arranged this scenario in second place in the order of the cards that represented his teaching strategy, he explained that:

ลังเลเพราะจริงๆแล้วจากการอบรมที่เราทำให้ครูดูหลายๆ อย่างแล้วก็สาธิตเนี่ย มันไม่ได้ใช้กระบวนการที่ครูต้องทดลองเองทั้งหมดเพราะว่าบางอย่างเอามาทดลองให้ดูหมดไม่ได้หลายๆอันที่เราทำให้ดูก็คือสาธิต

I hesitate in sorting this card because we demonstrated many activities to teachers during the PD. We did not allow teachers to do the investigation process, which is important. But, we used demonstration because we could not have teachers do every activity. So, we decided to demonstrate to them instead. (Piti, Card Sort Activity)

Piti indicated during the card sort activity that he did not walk teachers through an overview of the entire sound unit because he believed that teachers should know that already or they might do that themselves.

หลักสูตรบทเรียนเขารู้จักอยู่แล้ว มันไม่ใช่การเริ่มต้นการสอนด้วยการแนะนำอีกมันน่าจะใช้วิธีการแบบประเภท ถ้าให้เค้าทดลอง ก็แนะนำให้เขาลองทดลองดูซิ ให้สังเกตจากนั้นก็ป็นข้อสรุป มันควรจะเลียนแบบการสอนในห้องเรียนมากกว่า

Teachers already know the curriculum so we should not start teaching by introducing the curriculum. We should start by encouraging teachers to do activities and make observations and conclusions. The strategies used in PD should be parallel to classroom teaching strategies. (Piti, Interview #2)

Thus Piti agreed with the PD strategies in scenario 3, which represented an activity-driven orientation, in terms of selecting a variety of fun and easy-to-do activities for PD.

Piti exhibited activity-driven when he encouraged teachers to participate in an activity in order to verify the concepts on sound. Because his central goal for the PD was not to develop teachers' content knowledge, Piti did not pay attention to whether or not the activities that he provided for teachers develop conceptual understanding among the teachers.

Piti also displayed a didactic orientation when he indicated that some topics that were abstract could not be taught using the 5E model of instruction. Rather, Piti determined that when teaching abstract concepts, it was necessary that knowledge of those concepts would be transmitted by the professional developers to the teachers. As he indicated, some concepts were too difficult for the teachers to develop an understanding on their own. Thus, in his mind it was necessary to tell them. As he indicated, some concepts were too difficult for the teachers to develop an understanding of by themselves. Thus, it was necessary to tell them.

เรื่องของความถี่เพราะค่อนข้างจะเป็นนามธรรมทดลองก็ค่อนข้างจะยากสักนิด การที่จะนำไปสู่เรื่องของความถี่นี้ ถ้าคนที่ไม่รู้จักเรื่องของความถี่มาเลยมันอาศัยการบอกเสียส่วนหนึ่งเป็นการให้ความรู้โดยตรงเสียส่วนหนึ่งแต่การทดลองคงจะบอกไม่ได้ว่าเป็นความถี่ มันเป็นการบอกให้ท่องจำ

The concept on frequency is abstract, which need to tell teachers directly. Although we have some activities about this concept, they are difficult to understand. (Piti, Interview #2)

In addition to pedagogy-driven, activity-driven, and didactic orientations, Piti minimally displayed a discovery orientation when he indicated that:

ยุทธศาสตร์ที่ใช้คือเมื่อเค้าเกิดปัญหาแล้วเค้าก็อยากเรียน อยากรู้เพราะมันเป็นคำถามของตัวเอง จากนั้นเราก็ให้เค้าทดลองดู โดยเราอย่าเพิ่งบอกคำตอบเค้า ให้เค้าลองทำดู เช่น ถ้าเราอยากรู้ว่าเสียงเกิดจากอะไรก็ต้องทำการทดลองเพื่อให้ได้คำตอบ

My strategy is to make teachers develop problems about the topic and want to find out the answer. In this case, they will be ready to learn because the question is formulated by them rather than a teacher. Then, I will encourage them to do activity in order to find the answer. (Piti, Interview #2)

The excerpt above reveals that Piti displayed a discovery orientation because he tried to initiate a student-centered learning approach by encouraging teachers to formulate questions about sound concepts and perform activities in order to answer their own questions. However, during the PD implementation, although teachers raised several

questions about sound, Piti chose a question for teachers to investigate rather than one the teachers selected themselves.

In summary, Piti's philosophy contained multiple orientations to PD. His orientations that explicitly appeared during the PD implementation were pedagogy-driven. He also exhibited activity-driven orientation, didactic orientation and discovery orientation. However, these orientations to PD were not consistent and depended on the topic or scientific concepts that he taught in the PD. As in pedagogy-driven orientation case, Piti focused on the development of teachers' knowledge of using the 5E model of instruction, which he called *inquiry*. Opposed to other professional developers, Piti only presented two concepts in the sound unit to the PD teachers. He consistently was strict in his role as a model in teaching science using the 5E model of instruction rather than guiding teachers on the performance of activities and covering all concepts in the sound unit.

PCK for PD

Knowledge of teachers' understanding of science. Piti demonstrated his beliefs that the PD participants already had adequate content knowledge for teaching science. As Piti said, "unlike public school teachers, private school teachers had good basic concepts in science because most of them had science education background". (Piti, Interview #2) In addition, Piti believed that the concept of sound did not lead to any difficulties for teachers to understand. He believed, this concept was easy and he would not have any problems with teachers not understanding the concept.

เสียงเป็นเรื่องที่สวนใหญ่ครูมี basic concept อยู่แล้ว จริงๆ มันเป็น concept ง่ายๆ ในเรื่องของเนื้อหาเท่าที่ผ่านมามีปัญหาจริงๆเราก็คิดว่าตัวเนื้อหาเขาสามารถจะหาเอาเองได้

Sound is a fundamental concept, which teachers should know already without any difficulties to learn. They can find content knowledge everywhere. (Piti, Interview #2)

In addition, Piti believed that teachers could look for scientific knowledge from other resources such as a science textbook or the PD handbook. Thus, he believed the essential needs of teachers were how to teach science effectively based on the reformed National Standards. He also indicated that when the teachers did an activity, they would also develop or confirm their existing knowledge. These activities would help the teachers to make sense of the sound concepts.

Furthermore, Piti did not show any awareness of the need to find out teachers' prior knowledge. For example, Piti did not agree with scenario one of the card sort activity which had teachers draw a picture of sugar when it was put in water. He indicated that this activity is doable so drawing might not be necessary.

ของมันทำได้ เชื่อว่าอะไรก็ตามที่เขาสามารถจะทำได้ที่เห็นได้จากของจริง ควรที่จะทำจริง ไม่ใช่จินตนาการ

I believe that we should allow teachers to have real experience when it is possible. In regards to this activity [drawing picture of sugar in water], we should have teachers do it rather than have them imagine about it. (Piti, Card Sort Activity)

To teach this topic, as Piti reflected on the scenario one, teachers should be encouraged to do hands-on activity by putting sugar in water and observe the phenomenon instead of drawing a picture. He did not seem to realize that drawing a picture of sugar dissolving might provide a window for the professional developer to explore teachers' prior knowledge before learning a concept on dissolution.

Knowledge of PD strategies. Piti believed that there were 5 steps in teaching science. He explicitly demonstrated that 5E is inquiry. Piti used this strategy in the PD

because this teaching strategy was requested by Science Education Standards and IPST Curriculum.

การใช้กระบวนการ Inquiry ในการอบรมเอาอันแรกก่อนเพราะ สสวท. สนับสนุนให้ใช้กระบวนการนี้ในการจัดการเรียนรู้วิทยาศาสตร์ นั่นคือเรามีหน้าที่ที่จะต้องเผยแพร่ออกไป โดยทำให้ดู เราพยายามทำให้ดูโดยที่ไม่ได้บอกเหมือนการบรรยายว่า inquiry 5E ต้องทำอะไรบ้าง 1, 2, 3, 4, 5 อันนี้คือยุทธศาสตร์ที่ใช้

The IPST Curriculum requires the teachers to teach science using the inquiry process. So, it was our job to help the teachers understand this teaching technique. We tried not to tell them directly what the 5E was, but we modeled it to them by using this technique. (Piti, Interview #2)

In addition, Piti also believed that teachers had more interest in learning and doing science when they were engaged in the inquiry approach.

ก็น่าจะได้ คิดว่าเขาสนใจ จากการสังเกตว่าเขาตั้งอกตั้งใจทำใหม่ อาจจะมีส่วนน้อยที่เขาอาจจะเคยทำมาแล้วเท่าที่ดูมันก็ไม่น่าจะได้ถึง 5% ที่ไม่ค่อยสนใจเท่าไร คือเคยทำมาแล้ว หรืออะไรสักอย่าง หรือไม่ได้สอนเขาก็อาจจะไม่สนใจแต่เท่าที่ดูส่วนใหญ่ก็สนใจแล้วก็ทำ I think this strategy makes teachers interested to participate in learning science. They have attention in doing the activity. There might be some teachers who did these activities before, paying less attention to it, but I think it's less than 5%. (Piti, Interview #2)

The excerpt above reveals that Piti used the 5E model of instruction as his PD strategy because the teachers were requested by the Standards to use this strategy in their classroom. Piti thought that inquiry made teachers active in learning science, but it was still the professional developer's job to provide correct knowledge to the teachers. Piti exhibited the knowledge of the 5E strategy in that he was able to describe each phase of the 5E model, but he only demonstrated some phases to teachers. He also helped teachers to relate their experiences in the PD to a learner to experiences in a classroom.

Furthermore, Piti exhibited orientations to PD which were linked to the use of his PD strategies. For example, Piti reflected on scenario two during the card sort activity, say that having the teachers discuss and share their experiences before doing an activity wasted PD time and that teachers' discussion could easily be thrown off.

ไม่ชอบมากตรงที่ว่าครูพูดคุยเกี่ยวกับประสบการณ์ของตัวเองเกี่ยวกับเรื่องไฟฟ้าเนี่ย เค้าจะไม่พูดเกี่ยวกับเรื่องที่จะทำกิจกรรมเรื่องไฟฟ้าเพราะว่าสิ่งที่ใกล้ชิดตัวเค้าคือไฟฟ้าสลับ ไม่ใช่ไฟฟ้ากระแสตรง เพราะที่ผ่านมายุกันเรื่องไฟฟ้าสลับทั้งนั้นเลยแต่ไปเรียนกระแสตรงมันก็นำเข้าเรื่องไม่ได้สักที การเชื่อมโยงและอธิบายสิ่งที่เรียนรู้จากกิจกรรมเหล่านั้น อันนี้จริงๆ ก็คงจะ คือบอกได้ว่ามันเป็นอย่างไร แต่การเชื่อมโยงกับชีวิตประจำวัน เชื่อมโยงได้ยาก นำเสนอความรู้เรื่องไฟฟ้าที่ทดลองโดยนักวิทยาศาสตร์อันนี้จริงๆ แล้ว ถ้าที่อธิบายโดยนักวิทยาศาสตร์นี้มันใกล้ตัวมากเลย คนละอัน ยิ่งตอนท้ายยิ่งบอกกว่าความรู้ของตนเองกับนักวิทยาศาสตร์คนละเรื่องเลย

I don't like this scenario when it said allowing teachers to share their own experiences about electricity. I believe that their discussion will not relate to the lesson that we are going to learn. In the science curriculum, the electricity that they are going to learn is direct current. But, in their everyday life it is alternating current. So if we let them talk about their experiences, it won't get to the topic that we want them to learn. Connection to the everyday life is good, but it is too difficult for this topic. In addition, at the end the card said having the teachers compare their explanation to the scientists. The explanation by the scientists is too difficult to understand for the teachers and their explanation compare to the scientists would be like a different story. (Piti, Card Sort Activity)

Hence, Piti did not believe it necessary to provide time for teachers to express their knowledge about the particular topics either before or at the end of the PD.

Piti also displayed knowledge of PD strategies when he indicated that he selected only the activities on sound that allowed him to model the 5E model of instruction as well as were easy for teacher to understand the concept by doing activities. However, if he taught different topics in sound unit, such as frequency, he might use other strategies in helping teachers understand the concept.

การที่จะนำไปสู่เรื่องของความถี่นี้ ถ้าคนที่ไม่รู้จักเรื่องของความถี่มาเลยมันอาศัยการบอกเสียส่วนหนึ่งเป็นการให้ความรู้โดยตรงเสียส่วนหนึ่งแต่การทดลองคงจะบอกไม่ได้ว่านี่คือความถี่

To teach the concept of frequency, if they don't know about frequency before or they don't have knowledge or ideas about it, we have to give knowledge to them directly about what frequency is. Teachers or students cannot learn from doing the activity alone. (Piti, Interview #2)

If Piti had different goals for PD, such as to develop teacher's content knowledge, the 5E teaching strategy might not be appropriate for the PD. Consequently, it might be possible

that Piti would utilize other ways of representing the concepts instead of the 5E model of instruction in order to meet the new goals.

ส่วนการให้องค์ความรู้นั้นก็ก็เป็นสิ่งที่เราจะต้องให้ basic concept แก่ครู เราใช้กระบวนการทั้งหมดไม่ได้ เราก็ต้องให้องค์ความรู้โดยตรง การให้องค์ความรู้นั้นก็ต้องสอนวิธีการทดลองโดยใช้การทดลองเหมือนในห้องเรียนจริงให้เขาลองทำเป็นกิจกรรมการทดลองที่เราได้เสนอแนะไว้ในหนังสือเรียนให้เขาลองทำ แล้วให้ความรู้เค้าอีกที่ต้องมีการเน้นเนื้อหา

We have to give content knowledge to teachers. We cannot use the process, but have to direct them to knowledge. In case that the PD has emphasis on developing content knowledge to teachers, they have to do the activity similar to their students. Then, we provide content knowledge to teachers after the activity. (Piti, Interview #2)

Knowledge of PD curriculum. Piti minimally exhibited his knowledge of goals of the PD curriculum and also goals of the Science Education Standards. He indicated that teachers needed to teach science in a way that aligned with the requirement of the Standards.

กิจกรรมที่นำมาใช้ก็มาจากหนังสือเรียนที่เค้าใช้สอนกันในห้องเรียนนั่นแหละซึ่งเป็นไปตามมาตรฐานแน่นอน

The PD activities are selected from IPST Curriculum that most teachers use at school. Thus, our PD curriculum surely aligns with the Standards. (Piti, Interview #1)

However, there was not enough information to develop claims about what Piti knew about the PD curriculum.

Knowledge of assessment of scientific literacy. Piti's knowledge of assessment of teachers' scientific literacy seemed to be limited in terms of ways and aspects of teachers' learning that were important to assess within a sound unit. However, Piti expressed that in general the way that he employed to assess teachers' learning was from the discussion with teachers. He indicated that he noticed whether or not teachers had accurate understanding of the concepts by their questions during the PD.

จริงๆแล้วเราดูจากคำถามที่เขาจะถามเรากลับมาไม่มีการวัดและการประเมินผลในการอบรมก็จริง แต่เราสังเกตจากคำถามในบางเรื่องที่เขาไม่ค่อยมีพื้นฐานเนี่ยเขาจะมีปัญหาที่ถามทำ

ให้เราทราบว่าเขาจะอธิบายได้หรือไม่ได้ แต่นี่คำถามที่เขาถามมาเป็นคำถามที่ไม่ใช่ในเรื่อง concept หลัก อย่างที่บอกว่าโดยมากเขามีปัญหาในเรื่องเทคนิค

We don't have summative assessment, such as providing testing. We don't do that. We observe from teachers' questions. If they ask about the content, that means they don't have the concept. But, I never have those kinds of questions. Most questions are about techniques. (Piti, Interview #2)

Piti did not discuss what assessment instruments would be match to his goal for

PD of assessing teachers' ability in teaching science using 5E. As he indicated:

เราไม่ได้เน้นที่เนื้อหาซึ่งตรงนั้นสามารถวัดได้โดยการสอบ แต่เราเน้นที่กระบวนการสอนซึ่งก็ไม่ว่าจะวัดอย่างไร จริงๆ ถ้าจะวัดกันจริงๆ เราต้องให้ครูสอนให้ดู หรือไปดูเค้สอนที่โรงเรียน ซึ่งก็รู้กันว่าในทางปฏิบัติเราไม่มีเวลานั้น งานเราไม่ได้มีแค่อบรมครูและก็ไม่ได้อบรมแค่กลุ่มนี้กลุ่มเดียว เราทำกันตลอดปี ก็เลยไม่มีการวัดผลกัน

We don't focus on developing content knowledge for teachers, but we focus on the teaching process, such as how to teach in the classroom. If we did emphasize content, we could use testing. However, if we really want to assess and evaluate them, we have to follow teachers to their classrooms, which is not possible because we don't provide PD to this group of teachers only, but to many groups in an entire year. In addition, our tasks are not only the PD, we still have other tasks to do. (Piti, Interview #1)

In addition, Piti stated that there was not enough time for assessing teachers' knowledge of the content that they learned from the PD.

จริงๆแล้วเราควรจะมีการประเมินถ้าเวลาอำนวยมากกว่านี้ จริงๆแล้วเรามีการให้วุฒิบัตร ซึ่งเคยคุยกันในกลุ่มวิทยากรว่าเมื่อมีการให้วุฒิบัตรมันต้องสอบต้องผ่านการทดสอบประเมินผลเมื่อผ่านจึงจะได้วุฒิบัตร แต่ว่าในเวลาอันสั้นขนาดนี้ 1 ชั่วโมงต่อ 1 เรื่องมันคงจะทดสอบอะไรไม่ได้เพราะแค่เท่าที่มีการอบรมให้ความรู้และการทดลองมันก็ไม่พออยู่แล้ว

I agree that we should assess teachers IF we have more time. Actually, teachers will get a certificate. So, we discussed in a team many times that if we provide a certificate, we have to assess their learning. But, we don't have time for that part. As you can see, how do we have to hurry? (Piti, Interview #2)

However, Piti realized that assessment was a weakness of the PD. He stated that although he provided PD for many teachers, he did not know whether most of the PD participants really increased their content knowledge in the topics he taught when they left the PD.

ตรงนี้ยังขาดเรื่อง feed back ที่จะกลับมาว่าเขารู้เรื่องจริงหรือไม่ มันได้จากการสังเกตเท่านั้นเองว่าตอนนี้มีอันหนึ่งกรณีที่เราให้เขานำเสนอข้อสรุปจากการทดลองก็ดูแล้วปรากฏว่าเขาสรุปได้ แต่ทำไมทราบว่าเป็นข้อสรุปที่ได้ของกลุ่มซึ่งอาจจะมีการอภิปรายกันในกลุ่มแล้วส่วนบางคนก็ยังไม่มีความเข้าใจเราไม่ทราบเลยว่าเขาไม่เข้าใจ เพราะว่าในกลุ่มอาจจะมีคนที่เก่งแล้วก็มีความทำอะไรเลย

We don't have any feedback, this is what we need. So, we don't really know that they learn something. We can only tell from the observation and discussion during the implementation that teachers are able to develop conclusions from activities. But, if some teachers don't understand it, we will never know. There might be that within a group there are teachers who did activities and had good content knowledge while some teachers didn't participate in activity or they have poor content knowledge. We will never know. (Piti, Interview #2)

In summary, Piti's components of PCK for PD were limited. He believed that teachers already had good understanding of science knowledge for teaching primary grade students. He did not exhibit knowledge of teachers' misconceptions on the concept of sound. Although Piti could explain about the 5E model of instruction, he did not have accurate understanding of the elaboration step of the 5E. Piti did not explicitly display how much he knew about the PD and IPST curriculum. He only mentioned that the IPST curriculum supports the Standards. With regards to the knowledge of assessment, Piti generally used questioning and observation methods in order to measure teachers' understanding. His knowledge of ways and aspects of teachers' learning that were important to assess within a sound unit was limited. Piti also did not show how much he understood about assessment methods.

Vimon's Implementation, Orientation, and PCK for Professional Development PD Implementation

Vimon took responsibility in teaching the electricity and magnetism unit for this PD. She started her session by introducing materials that the teachers would utilize with their students in order to engage them in the science lessons. Vimon stated to the teachers that playing some games or magical science activities would initiate the students as to

how that phenomenon occurred. Compared to other professional developers such as Piti, Vimón explicitly modeled and explained only the engagement step in the 5E Learning Cycle. She did not model or provide knowledge of the remaining four steps of the 5E Model.

During the PD implementation, Vimón did not have the teachers do many magnetic activities. She mainly introduced materials and manipulatives that the teachers could find at the schools. She also talked about students' prior experiences with magnets. She indicated to the teachers that the students already knew about the topic of magnets before they came to the classroom. However, their understanding about magnets might not be classified as scientific understanding. Thus, it was the job of the teachers to help the students develop scientific understanding of magnets. Vimón was the only professional developer in this study who mentioned a misconception that teachers might have. She mentioned that primary teachers might have the same misconception as the students, which is the idea that magnets stick to *all* metals. When the teachers had this misconception, they were likely to transmit it to their students as well. To address the teachers' misconception, Vimón indicated that when the teachers did laboratory activities and observed the results of those activities, they would finally correct their own misconceptions. The magnet topic was the only place where Vimón mentioned the possibility of teachers' misconceptions.

During the PD implementation, the PD strategy that Vimón utilized was to immerse the teachers in the hands-on activity that she prepared for them. During the PD implementation, Vimón asked the teachers "what materials could stick to a magnet." When the teachers said, "metals," Vimón gave examples of many types of metals

including copper, iron, zinc, etc. Then, she asked the teachers whether or not a magnet could stick to all metals. Rather than asking the teachers to formulate their own explanation from the activity, Vimom explained to the teachers that only the metals that have the property to magnetize can stick to the magnet. Vimom only spent a few minutes with the magnet unit. She did not assess the teachers' understanding of this concept but moved to another topic in this unit.

Vimom utilized the majority of the PD time in introducing how to duplicate unit activities. She prepared extra handouts with directions for creating these materials. The next unit was an electricity unit, which she began with the topic of static electricity. Similar to the previous unit, Vimom used most of the time in introducing materials and how to duplicate those materials. She allowed teachers to do some activities on this topic. Vimom believed that the students would be very excited if the teacher acted like a magician in the science classroom, especially during the engagement phase. She also believed that if the teachers used materials that were colorful, the students would pay more attention to the activities. For instance, at the beginning of the static electricity unit, Vimom engaged teachers with the activities that made her seem to do magic. She wiped a plastic rod with a napkin then placed the plastic rod into a cup filled with colorful foam seeds. When she pulled the plastic rod out of the cup, many colorful foam seeds stuck to it. Vimom asked the teachers, "See, I have magic, right? Did I put glue on the plastic rod? How did the foam stick to it?" One teacher stated that it occurred because of static electricity. Vimom said, "O.K. I have very smart students. So, how do you feel? Do you feel like you want to learn now?"

Then, Vimom reminded the teachers that what she just did was a teaching technique to lead the students into the lesson. Vimom prepared many activities for the static electricity unit. During the time that teachers were doing activities, Vimom presented her PowerPoint presentation about scientific background related to static electricity. However, the teachers paid attention to their activities more than listening to her. In spite of this, Vimom kept showing her slides without stopping or asking for the teachers' attention. After the activity and Vimom's presentation, she did not ask teachers what they understood. The last activity for her session was lighting a light bulb with 3 limes. Because the time was limited, this activity was very rushed. Vimom asked the teachers to make a circuit with limes, wire, bulb, and copper metal sheets. Vimom explained the information on circuits and electricity while the teachers were doing their activity. Only the teachers who did not get involved in the activity listened to her presentation.

Orientation

Figure 12 represents my analysis of Vimom's orientation to PD. I found that, during the interviews and PD implementation, Vimom's orientation to PD consisted of two central goals and three peripheral goals. Her central goals were 1) to provide scientific activities that work for the PD participants, and 2) to provide ideas and support to the teachers in order to encourage them to implement those activities in their classroom.

ให้ครูสามารถกลับไปจัดกิจกรรมที่โรงเรียนได้เน้นในการทำกิจกรรม แนะนำในเรื่องที่เขา
คาดไม่ถึง แนะนำการหยิบใช้สื่อที่อยู่รอบๆตัวมาใช้ ครูมักจะบอกว่าไม่มีสื่อที่จะทำการ
ทดลองนำสิ่งที่เขามีอยู่แล้วมาใช้ หรือถ้ามันไม่มีก็แนะนำวิธีประดิษฐ์สื่อง่ายๆทำได้เองไม่
ต้องลงทุนสูง

I want teachers to implement activities they learned at PD in their classroom. I will suggest them about things that they don't know before, such as what other materials they can use instead of materials

recommended in a book or suggest them to duplicate the inexpensive manipulatives to use at their school. (Vimon, Interview #1)

To support these goals, Vimon required as many activities as possible for the teachers to do. Vimon also provided ideas on how the teachers could modify other materials in the instructional kits. Vimon believed that teachers and students were alike in terms of they were attracted with fun and exciting activities, which led them to pay more attention in learning. Vimon also indicated that when the teachers were able to do those activities, knew how to modify other materials to use in the activities, and get excited over the activities, then they would implement those activities in their classrooms because they wanted the students to have experiences like they had in the PD.

ถ้ากิจกรรมมันตื่นเต้น สมมุติเราเล่นกลทุกคนจะชอบ พอมีอะไรตื่นเต้นเค้าก็จะชอบก็จะสนใจแล้วก็ตั้งใจเรียน เดี่ยวครูจะเอาไปเล่นบ้างกับเด็ก ครูเหมือนเด็ก โขวหน้าห้องเรียกความสนใจเด็กได้ เขาก็คิดว่าเอาแนวคิดนี้ไปใช้กับเด็ก

If the activities are exciting, such as we do magic things, the teachers will like them and pay attention to activities and learning. Like when they get excited and wonder about the activities, they will want to know the answer. Then, they will do the similar things that they learn at PD with their students because they know this would draw the students' interest. (Vimon, Interview #1)

Vimon stated that her goal in delivering the Magnetism and Electricity session was to provide activities for teachers rather than to develop their content knowledge. The criteria that she used in choosing PD activities were: 1) easy to implement in classroom, 2) requiring inexpensive manipulatives, and 3) fun and exciting.

คืออย่างที่สอนไปนะก็จะสร้างความสนใจ และแนะนำกิจกรรมว่าใช้กิจกรรมไหน กิจกรรมนี้มันสอนเรื่องอะไร สอนแล้วทำกิจกรรมนี้มันเกิดได้ยังไง ครูได้ประโยชน์คือได้วิธีการจัดกิจกรรมในห้องเรียน

You can see in the PD, I mainly introduced activities, helping teachers to know how to make it work, providing tips for them to use this activity with students, or providing results of activities. So, for this PD, teachers will have benefits in terms of knowing techniques in organizing their science classroom. (Vimon, Interview #1)

วัตถุประสงค์ของเราไม่ได้ต้องการที่จะไปพัฒนาความรู้ของครู แต่ต้องการที่จะให้กิจกรรมและกิจกรรมต่าง ๆ ที่เราเลือกมาใช้ในการอบรมทำไมเราถึงเลือกกิจกรรมพวกนี้ เพราะเหตุ

ว่า 1. ใช้ไปสอนเข้าใจง่าย 2. สื่ออุปกรณ์หาได้ง่ายไม่ต้องลงทุนสูง 3. มันน่าตื่นเต้น อย่างกิจกรรมเม็ดโฟม

My goal was not to develop the teachers' content knowledge, but to provide activities. These activities must be (1) easy to understand, (2) reasonably priced, and (3) exciting. (Vimon, Interview #2)

Vimon believed that, for teaching science at elementary grades, teachers did not need to have deep content knowledge because concepts of any science areas at elementary levels were fundamental and not complicated. As Vimon said:

ครูดูจากคู่มือครูของเราส่วนมากเนื้อหาที่จะอธิบายเด็กก็พอแล้ว ถ้าครูไม่คิดที่จะไปเอาอะไรมาอธิบายสเปสปะ ครูอธิบายแค่ตามการทดลองเนื้อหามันก็เพียงพอแล้ว แต่ครูปัจจุบันนี้ชอบไปหยิบยืมท้องมาแล้วเอามาสอนพยายามให้เนื้อหาเด็กเยอะๆ รู้แค่ concept ที่จะให้เด็กรู้ก็พอแล้ว รู้แค่ที่จะเอาไปสอนก็พอแล้ว มันก็ยังไม่ได้ประยุกต์อะไรมา มันก็ตาม concept เบาะๆ ทุกอย่าง เพียงแต่ว่าอาจจะมีเด็กเก่งที่ถามขึ้นมาตรงนี้ครูก็ต้องรู้ว่าครูต้องเตรียมมากแค่ไหนเพราะแต่ละโรงเรียนเราก็ไม่รู้ว่าเป็นยังไงเพราะเนื้อหาประถมมันไม่ได้ลึกมากมาย มันแค่ผิวๆไม่ได้เข้าไปในตัวอุปกรณ์แต่ละชิ้นมาก

Teachers only need to look at the teacher-guided book. We provide everything including knowledge for teaching to them. Teachers don't need to look for other information or knowledge from other resources. Only what we provide for them is enough. So, teachers only know what they have to teach is enough because teachers like to give a lot of knowledge to students, which I don't understand why. Content knowledge for elementary students is superficial and does not need specific knowledge to help students understand it because most of them are concrete concepts. If the teacher follows the directions, they won't have problems. (Vimon, Interview #1)

Vimon believed that knowledge provided in a teacher-guided book was enough for teachers to teach science at elementary grades. Teachers did not need to deal with abstract concepts that needed deep content knowledge to be transformed for their students. She mentioned that most of the science concepts at this level were simple and concrete. However, when she was asked about knowledge appropriate for teachers during the PD, Vimon indicated that she would provide knowledge that was slightly higher than it was in the teacher-guided book because there might be some student questions that went beyond the curriculum, so teachers would need to be able to answer those questions.

เราจะให้สูงกว่านิดนึงเพื่อเด็กเก่ง ให้เนื้อหาเพื่อว่าครูสามารถอธิบายหลักการตรงนี้ได้บ้าง อธิบายให้เด็กเข้าใจได้

In terms of content knowledge, it might be slightly deeper than it is in the teacher-guided book. Sometimes there are students who have good science knowledge in that classroom, so teachers can have knowledge to explain to them. (Vimon, Interview #1)

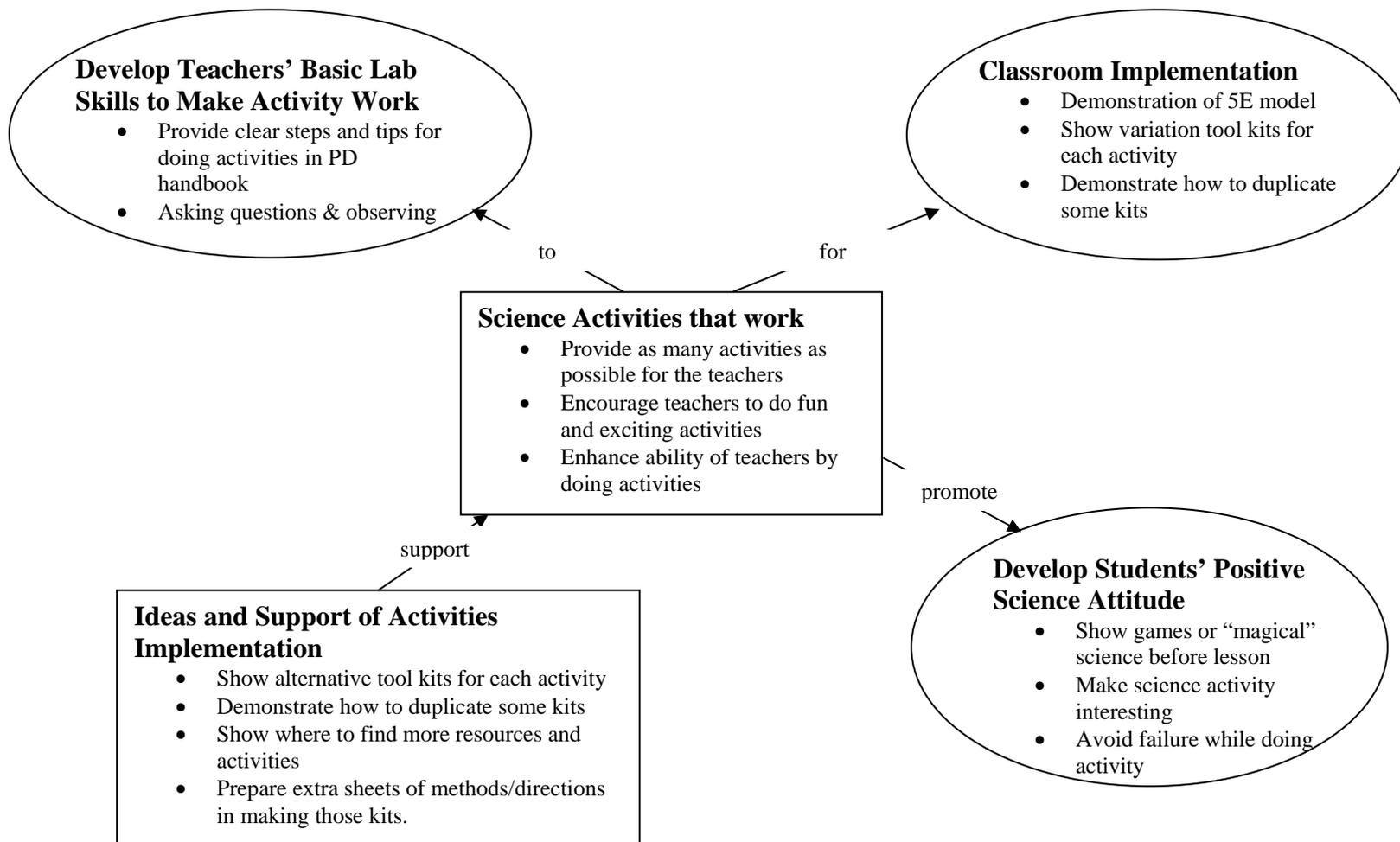
Vimon also displayed her belief that teachers came to the PD because they needed to know about activities to use with their students. In addition, the PD did not have enough time to help teachers develop understanding about the concepts. So, teachers needed to help themselves by reviewing the resources in order to recall their existing knowledge.

เรื่องของเนื้อหาที่สอนในช่วงเวลาแค่นี้มันไม่พออยู่แล้ว อีกอย่างครูเขาควรจะมีการศึกษาเนื้อหาเพิ่มเติมเองด้วย ความรู้แค่นี้ก็ต้องอ่านเพิ่มเติมด้วย ที่เขามาหาเราตรงนี้เขาอยากได้กิจกรรม

We don't have time to visit content knowledge within 3 hours of the PD session. You can see that we had to rush during the implementation. In addition, teachers need to go back and read about content knowledge on their own. However, I think they come to PD because they want activities. (Vimon, Interview #2)

Vimon's knowledge and beliefs about the purposes and goals of PD related to her teaching behavior during the PD implementation in that Vimon did not pay adequate attention to teachers' development of understanding of concepts. Even though she presented some content knowledge on these concepts through the PowerPoint presentation at the end of each concept, Vimon spent most of the PD time talking about tips and techniques that teachers could use with their students in order to capture their attention. She also devoted PD time in providing information to teachers about the methods in making the activity kits that she showed in the session.

Figure 12. Vimom's Goals for PD



□ = central goals; ○ = peripheral goals

Figure 12 also illustrates that Vimom's peripheral goals were: 1) to develop laboratory skills that were necessary to make the activities work, 2) to promote classroom implementation using PD activities, and 3) to develop students' positive attitude toward science. According to these goals, Vimom generally provided clear steps and tips of doing activities in PD handbook and during her implementation. She also provided a variety of activities that introduced the same science concept in order to help teachers to have more choices in selecting activities to use with their students.

พยายามแนะนำกิจกรรมให้กับครู เพื่อที่ให้ครูเอาไปใช้สอน เพราะว่าเท่าที่ดูคือพยายามให้กิจกรรมไปเยอะ ๆ อย่างไฟฟ้าสถิตก็มีหลาย ๆ กิจกรรม น่าจะช่วยให้ครูเกิด Idea มากกว่าก็คือจะสอนเรื่องนี้ เดี่ยวนี้เขาใช้อุปกรณ์สื่อตรงนี้ที่เค้ามียังในห้องไปสอน Idea ที่เขาจะใช้อะไรไปสอนให้เข้าใจง่าย
I tried to introduce as many activities as possible to teachers. So, they would use some of those activities in their science instruction. For example, I gave them many activities about the electrostatic concept.
(Vimom, Interview #2)

In addition, during the PD implementation Vimom always mentioned to the teachers that they needed to make activities exciting for the students. She also warned the teachers that failure to do the activities would develop students' negative attitude toward science. Thus, it was necessary for the teachers to understand how to conduct activities and how to help students make those activities work.

เพราะครูยังเข้าใจผิดอยู่ อย่างเซลล์มะนาวถ้าครูเขาไม่ได้ทดลองเองนะคะ ครูเปิดหนังสือ text ฝรั่งเศสหรือหนังสือไทยที่แปลมาในรูปเขานะ มะนาว 1 ลูก หลอดกลมหลอดหนึ่งเอามาต่อกันทำงานไหมคะหนังสือติดแต่เอามาทดลองจริง ๆ มันไม่ติดมะนาวลูกหนึ่งมันได้กระแส น้อยมากๆ แล้วหลอดไฟหลอดกลมมันใช้สูงกว่านั้นมะนาว 3 ลูกยังไม่ติดเลย ก็เลยบอกเขาว่าถ้าอาจารย์ไม่ลองทำดูก่อนแล้วให้เด็กทำตามหนังสือเด็กทำยังไงมันก็ไม่ได้ เขาเริ่มเกิดความรู้สึกที่ไม่ดีต่อวิชานี้แล้วทำยังไงก็ไม่ดีจะสร้างความรู้สึกลบๆ ให้เด็กถ้าเริ่มวงจรแรกเขาทำได้แล้ว work เขามีความสามารถนะต่อไปเขาจะตั้งใจเรียนเรื่องนี้มากขึ้น
Most teachers misunderstood about the activity of making a bulb light with a lime. Many teachers don't try the activity before using with students by following the activity direction. Then, they found that the bulb won't light, but they don't know why. So, I have to tell them that they need to try the activity before giving to the students. Otherwise, students will have bad attitude with the failure of the activity. So, if we have students do something that works like making a circuit and seeing the

bulbs light, they will be proud themselves and have intention to learn science. (Vimon, Interview #1)

อาจารย์ต้องลองทำกิจกรรมก่อนที่อาจารย์จะเอาไปให้เด็กทำ เพราะถ้าเด็กทำแล้วมันไม่ได้ผล อาจารย์รู้มั๊ยคะว่าอาจารย์กำลังทำร้ายเค้า ทำให้เค้าไม่ชอบวิชาวิทยาศาสตร์ ทำให้เค้าเกลียดวิทยาศาสตร์

If you did not test it yourselves before letting your students do the activity and a failure occurred, you made a critical mistake with your students because you may have made them hate science (Vimon, During PD Implementation).

Table 7 showed Vimon’s arrangement and reflection on the scenarios that she thought they were represented her PD teaching and ideal PD strategies.

Table 8

Vimon’s Arrangement and Interpretation of the Card-Sort Scenarios

Items	Scenarios	Vimon’s Interpretations
3	You, as a professional developer, set up PD lessons for a unit on heat conduction. You introduce heat conduction activities for a 6 th grade elementary book. You select a variety of fun, and easy-to-do activities for PD. (activity-driven)	“It needs to be various because the teachers might not be able to develop understanding within the first activity, but they might understand it in the later activities. It likes repeat it again and again in introducing the same topic.” (activity-driven)
10	You, as a professional developer, have teachers first engage in laboratory activities in a book, class discussion. You will end each activity with your explanation of science knowledge beyond those activities. (didactic)	“This scenario is quite similar to scenario 9. However, there are 3 steps in this scenario including engaging in laboratory, discussing, and explaining. So, I think it is O.K and I use these strategies as well.” (didactic)
8	You, as a professional developer, design a PD lesson on dissolution by encouraging teachers to do activities that their students would do. At the end of session, you assign teachers to discuss within their group, then as a whole about what they learn about dissolution and about teaching this unit. (reflective)	“When the teachers do activities that are same ones as the students, they knew in each activity what and where they should observe, what to emphasize to the students, and what knowledge to add to the students. If they did activities that were different to the activities performed by their students, they may overlook the important things that the students should know.” (activity-driven)
11	Teachers are intrigued with a Thai flute that a classmate has brought to school. As a group, the teachers identify questions and ways to explore how the flute works. You help the teachers organize into investigation teams, and you investigate along with the teachers. (guided inquiry)	“In order to tell or direct teachers to every single thing, this scenario shows that teachers have questions, which we can encourage them to investigate in order to answer their questions. I like this strategy because teachers generate question themselves without our guidance.” (discovery)

Table 8 (continued)

Items	Scenarios	Vimon's Reflections
7	As a professional developer, you want teachers to learn about how sound is produced. You decide the best way to do this is to demonstrate teachers with various musical instruments to verify a science concept of vibration produces sound. (academic rigor)	"This scenario is similar to scenario three. But, I don't like the word <i>demonstration</i> . I think we should provide hands-on experiences to teachers when they come to PD. If we use demonstration technique, they will use this technique with students as well." (activity-driven)
15	As a professional developer, you begin a unit of heat conduction by engaging in activities that you hope the teachers will use with their students. You demonstrate teachers to use whiteboarding and cooperative learning in teaching those activities. (pedagogy-driven)	"I think it is good strategy, which I will use it in future. However, we should have teachers do it instead of demonstration."
13	You, as a professional developer, have teachers observe a music instrument and generate questions about how sound is produced. Each group designs and carries out their own experiment to test a hypothesis related to the group's questions. (inquiry)	"The strategies stated in this scenario are not doable in the PD, such as design and carry out their own experiment, but I think it is way how science should be taught. But, like classroom teaching, to meet the PD plan, we can't use these strategies in the PD."

Vimon placed scenario first because she mentioned that:

มันควรจะมีหลากหลาย มันเหมือนทำซ้ำนั่นแหละ concept เดียวกันแต่ให้ครูทำกิจกรรม
หลายๆ แบบ เพราะกิจกรรมแรกเค้าอาจจะยังไม่เข้าใจ

It needs to be various because the teachers might not be able to develop understanding within the first activity, but they might understand it in the later activities. It likes repeat it again and again in introducing the same topic (Vimon, Card Sort Activity).

Her reflection during the card sort activity was supported by her implementation in the PD in that she selected many activities from the IPST curriculum that introduced the same concept to teachers. However, instead of allowing teachers to do every activity on the same concept, she chose an activity for teachers to participate in and went through other activities as the alternative ideas. During the interview, Vimon believed that:

ครูเขาอยากได้กิจกรรม อยากได้การทำสื่อ ใช้วิธีแนะนำกิจกรรมแนะนำสื่อว่าจะใช้สื่อตัวชี้
สอนยังไง เน้นไปแต่ละตัวให้มันมาก ไม่ใช่ไปเร็ว ๆ ก็คือ อย่างกิจกรรมไฟฟ้าสถิตเราก็
เลือกเอาสักตัวหนึ่งให้มันโอเค แล้วค่อยไปแนะนำตัวอื่นเสริมว่าเอาทำที่ไปเร็วให้เป็น
ทางเลือก เอาเสียอย่างหนึ่งที่มันลงลึกไปเลย ส่วนมากกิจกรรมที่เราแนะนำสื่ออะไรอย่างนี้
Concept มันจะคล้าย ๆ กัน แต่มันต่อไปอีกนิดหนึ่ง

Teachers need activities, media, and suggestions for doing activities in terms of how to use these activities or media in their science instruction. For example, when teaching the electrostatic concept, I will place more emphasis on one activity than the other in order to help them have clear understanding about that activity. For the remaining activities, I won't go into many details, but introduce to them as alternative activities. (Vimon, Interview #2)

Vimon arranged scenario 10 in second place because this scenario covered three steps that she used in the PD in that teachers had opportunities to do the activities and discuss them. Then, the professional developer provided explanations of science knowledge at the end of activities.

มันก็คล้ายกับหมายเลข 9 นะแต่มันเปิดโอกาสให้อภิปราย มีการกระตุ้น อภิปราย แล้วก็สนทนา มี 3 ขั้นตอนเลย โอเคเลยนะ เพราะที่ท่าอยู่เราก็ใช้วิธีนี้
This scenario is quite similar to scenario 9. However, there are 3 steps in this scenario including engaging in laboratory, discussing, and explaining. So, I think it is O.K and I use these strategies as well. (Vimon, Card Sort Activity)

In addition, Vimon compared this scenario with scenario 9 and stated that the strategies of these two scenarios were alike. However, she did not think the professional developers had to introduce or explain about curriculum to teachers. Vimon indicated that she did not agree that the PD sessions started with introducing the Science Standards and IPST curriculum. As she mentioned before, because teachers already taught science in their schools, they should already know what was required in the curriculum, what they had to teach, and what the students needed to know.

หลักสูตรนี้ครูเค้าสอนที่โรงเรียน เค้าก็ต้องรู้อยู่แล้ว เราไม่ได้พูดถึงหลักสูตรเลยนะ เพราะกิจกรรมที่เราสอนเค้ามันก็มาจากหลักสูตรอยู่แล้ว เราจะไปให้ความรู้เกี่ยวกับการใช้วัสดุอื่นที่เป็นทางเลือกมากกว่าถ้าไม่ใช่ตัวนี้จะใช้อะไรแทนได้ ข้อ 9 นี่หลังๆ จะเหมือนแต่ไม่เหมือนตรงอธิบายหลักสูตรนี่ละ
Teachers have to know the curriculum because they use it at school. I won't talk or explain about the curriculum to them again. Instead, I will suggest what alternative materials they can use when they don't have materials that are stated in the curriculum. Scenario 9 is closed to me, except explaining the curriculum. (Vimon, Card Sort Activity)

However, although Vimom mentioned that teachers' discussion about their existing knowledge and experience was important, it was not doable in the PD because of the limited time. She indicated that it was necessary for the professional developer to provide correct scientific knowledge to the teachers.

During the card sort activity, Vimom displayed contradiction about her PD strategies. Vimom agreed with scenario two in that it had all the fundamental steps that teaching science should have. She indicated that:

จริงๆ อันนี้มันเป็นวิธีพื้นฐานเลยนะ คือดูก่อนว่าครุเค้ารู้อะไรมาบ้าง เค้ามีความรู้พื้นฐานอะไรก่อนจะเรียนเรื่องนี้บ้าง จากนั้นก็ให้ครูทำกิจกรรมแล้วก็อธิบายผลการทดลอง แล้วเราก็มายอธิบาย นำสิ่งที่เค้าได้จากการทดลองมาเปรียบเทียบกับสิ่งที่ถูกต้องว่าที่ตัวเองรู้เนี่ย ถูกมั๊ย

Actually these are basic steps. At the beginning of the session, we need to check the teachers' prior knowledge. Then, we allow the teachers to do activity and discuss their results. After that, we have to explain the accurate concepts to them and allow them to compare between their explanations and the scientific explanations. (Vimom, Card-sorting Activity)

However, Vimom indicated that she did not use these strategies in the PD because there were impossible to do in the PD. First of all, she said, the PD time was restricted so she did not have enough time to have the teachers talk about their experiences in order to check their prior knowledge. In addition, many teachers participated in the PD and each PD participant had different prior knowledge. The PD could not check all PD participants' knowledge. Thus, the only possible way was to teach it with the assumption that teachers did not know anything.

จริงๆ มันทำไม่ได้ เพราะว่าเราไม่ได้สอนครูคนเดียว ครูแต่ละคนก็มีความรู้พื้นฐานที่หลากหลาย แล้วเราสอนที่ 50-60 คน เราก็คงสมมติไปเลยว่าเค้าไม่รู้ แล้วเราก็คงสอนตาม concept ของเราไปเลย

Actually, we can't really do it because we don't teach only one teacher but we have 50-60 teachers. Each individual teacher has different knowledge background. So, I assume that they don't know any and keep my teaching on plan. (Vimom, Card Sort Activity)

Another example of a contradiction about appropriate PD strategies occurred when Vimon reflected on scenario four. She determined that the strategies used in that scenario were not flexible. Vimon indicated that she did not like to give materials to the teachers. Giving materials to the teachers developed a misunderstanding with the teachers in that if they did not have their materials, they could not teach those activities at schools.

มัน fix เกินไปหรือเปล่า เป็นขั้นเป็นตอนชัดเจนสื่ออุปกรณ์ก็เอาจากตรงนี้ไปด้วยมัน เหมือนว่าอีกหน่อยถ้าไม่มีอุปกรณ์ก็สอนไม่ได้ จริงๆ ควรจะแนะนำเป็นกิจกรรมที่แนะนำว่า ถ้าไม่มีตรงนี้จะเอาอย่างอื่นได้มั้ย ขั้นตอนการทดลองก็น่าจะพลิกแพลงได้
It is too specific in terms of providing clear steps for teachers. I think it should be more flexible by leaving a space for teachers to modify or making decisions. In addition, I don't like the idea of giving materials to teachers to use at school because they will ignore to allow their students to do some activities that they don't have materials for. So, we should train teachers to be able to modify other materials for doing the activity.
(Vimon, Card Sort Activity)

Vimon said she would prefer to give a variety of activities for the same concept to the teachers. Then, it was their job to decide what activity they wanted to use with their students. She also provided alternative materials that the teachers could modify when teaching science. However, Vimon was hesitant to put this scenario in the “not like me group,” but put into the “can't decide” group instead. Vimon explained that if the teachers followed the directions step-by-step, they would learn and practice the correct scientific process.

แต่จริงๆ ให้ทำเป็น step ครูก็จะได้กระบวนการที่ถูกต้อง ให้ทำเป็นขั้นเป็นตอนแล้วเราก็ช่วยเน้นให้เค้ามันก็มี science method ดีนะ
However, teachers will develop laboratory skills when they follow the steps that we provide in the direction. It sounds like teachers will surely have scientific methods if they followed the steps. (Vimon, Card Sort Activity)

Another example of Vimon's dual beliefs about PD was exhibited when she reflected on scenario 6 and 14. On scenario 6, Vimon mentioned that she would allow the teachers to explore an ice brick freely based on their interest. Vimon determined that

sometimes the teachers' observations were beyond professional developers' expectations.

Thus, the professional developers should not direct the teachers what to observe.

However, when Vimom was asked to reflect on scenario 14, she indicated that she disliked the strategy of having the teachers investigate a variety of materials at the back of a room.

เราต้องให้แนวคิดเค้า (ครู) ด้วย เหมือนมีคนช่วยเค้าอีกแรงใน ทำให้การที่จะไปให้ถึง เป้าหมายก็จะง่ายกว่าการปล่อยให้เค้าไปแบบสะเปะสะปะไปทั่วกว่าจะได้ concept ซึ่งเราก็ไม่รู้ว่าเค้าได้หรือเปล่า แล้วบางคนไม่ได้เราก็คงไม่รู้อีก
We need to give them (teachers) some ideas. If we help them, they will easily meet the goals. It takes a long time for them to learn something if we let them explore and learn on their own. And we won't be able to know whether or not they learn something. (Vimom, Card-sorting Activity)

She mentioned that scenario 14 was too broad and seemed uncontrolled. When asked to change the strategies in the scenario to parallel her own strategy, Vimom stated that:

เราต้องช่วยเค้าด้วย guide เค้าคิดว่าจะดูอะไร ไม่ใช่ปล่อยให้เค้าไปเล่นเองแล้วไม่สรุปอะไรเลยมันก็ไม่ได้ concept ซะที
We [the professional developers] have to guide to the teachers on what to investigate. This also includes having the teachers discuss with each other. Otherwise, the teachers would be out of track and the professional developers would have difficulties in guiding them to the concepts. (Vimom, Card-sorting Activity)

Vimom indicated that it was similar to teaching science in the classroom. The teachers already planned what they wanted the students to learn. If the teachers used the strategies in scenario 14, they would not be able to meet their goals. In addition to providing guidance in discussion and exploration, Vimom stated that explaining the correct concepts to the teachers should also be added to scenario 14. She elaborated her idea by stating that wrapping up the scientifically correct concepts was needed to make sure that every teacher knew what they should learn from those activities.

Vimon arranged scenario 8 in third place in terms of how its strategy was similar to her PD strategies. Vimon indicated that PD should be designed in a way that the PD participants were involved in the activities as if they were their students because they needed to know how the activities worked. In addition, the teachers also needed to develop an awareness of the activities that they would teach. This claim was supported when Vimon did the card sort activity. She agreed with scenario 8 that the professional developer should prepare activities for the teachers that were similar to their students' activities. As Vimon said, the professional developers should adopt the role of the teacher and model to the teachers how teaching science should be.

ครูต้องทำกิจกรรมเหมือนเด็ก ครูจะรู้ว่ากิจกรรมนี้มีตรงไหนต้องเน้นหรือเพิ่มเติม ไม่ควรทำแบบว่าให้ครูทำกิจกรรมหนึ่งแล้วให้นักเรียนทำอีกกิจกรรมหนึ่ง เพราะบางทีกิจกรรมที่
ให้เด็กทำแล้วครูไม่ได้ทำ เค้าอาจจะมองข้ามจุดสำคัญๆ ไป

When the teachers do activities that are same ones as the students, they knew in each activity what and where they should observe, what to emphasize to the students, and what knowledge to add for the students. If they did activities that were different to the activities performed by their students, they may overlook the important things that the students should know. (Vimon, Card-sorting Activity)

Vimon's reflection on scenario 7 supported her reflection on scenario 8 in that professional developers should provide hands-on experiences to teachers as much as possible because teachers would implement the same techniques that they learned from PD in their classrooms.

อันนี้มันก็คล้ายกับ 3 ละนะ แต่ไม่ชอบคำว่าสาธิต คิดคำว่าสาธิตนี่ละ เราน่าจะให้ครูได้เห็นได้ทำจริงๆ เพราะไม่จั้นเค้าก็เอาไปสาธิตกับเด็กนั่นละ

This scenario is similar to scenario three. But, I don't like the word *demonstration*. I think we should provide hands-on experiences to teachers when they came to PD. If we use demonstration technique, they will use this technique with students as well. (Vimon, Card-sorting Activity)

In summary, it appears that Vimon tried to introduce many activities for each unit. As opposed to other professional developers, she neither focused on developing teachers'

understanding of the 5E model of instruction nor modeled how to teach her units using the 5E strategy. During the interview, Vimom indicated that the teachers knew more than her about pedagogical knowledge because they took courses in college and had more teaching experiences in primary grades than her. Vimom indicated that one of the problems in teaching science at school was that the teachers did not allow their students to do activities. She mentioned that the primary teachers made excuses that they did not have materials. During the PD implementation, Vimom emphasized how the teachers could find materials in their schools and elsewhere. She also introduced many alternative activities and ideas that teachers could use to generate projects for students after they learn these units. In addition to the introduction of materials and ideas, she also focused on providing direct experiences with the activities that they could use in their classrooms.

Lastly, Vimom believed that it was her job to guide teachers on how to make the activities work, and how to find alternative materials that were inexpensive and attractive to students. Vimom believed that the teachers knew the concepts well enough in these two units. They could also look for additional knowledge in other resources such as science textbooks, the PD manual, and/or by asking experts. She did not see herself as eligible to provide the content knowledge and pedagogical knowledge to the teachers because of her age and her less experience in teaching science. Vimom displayed multiple orientations to PD including an activity-driven orientation and a didactic orientation. Vimom exhibited activity-driven orientation in that she believed that the teachers should learn and do the activities that their students would do in the classroom. During the PD, Vimom provided as many activities as she had planned for the teachers. She did not pay attention as to whether or not the activities that she provided for teachers helped them develop

conceptual understanding about the particular concepts. Vimon believed that, during the PD, professional developers might allow the teachers to explore independently, but they needed to provide the accurate scientific knowledge at the end of the activities. Vimon displayed a didactic orientation in that she believed that content knowledge could be transmitted through textbooks, other written resources, and direct explanation.

Vimon displayed her belief that teachers should learn in the way that they had to teach. Thus, when sorting the cards, Vimon did not only think about the strategies used in the PD, but expressed concern about whether or not those PD strategies could be implemented in the typical science classroom. Thus, sometimes Vimon liked the PD strategies represented in the card scenarios. However, she put those cards in the “not like me” or “can’t decide” group if she believed the strategies stated in the scenarios were not doable in the classrooms. Vimon’s existing experiences in providing PD and knowledge about PD guided to her dual beliefs about how PD should be implemented. For example, many times that Vimon agreed with the strategies in the card sort scenarios in terms of good PD strategies, but believed those strategies were not doable in the PD.

PCK for PD

Knowledge of teachers’ understanding of science. Based on Vimon’s knowledge of teachers’ understanding of science, her belief was similar to other professional developers’ beliefs in that teachers, especially the private school teachers, had adequate knowledge in science for the primary (1-6) grades, including the topic of magnetism and electricity. She believed that the teachers might not have difficulties in either understanding or teaching the magnet unit. However, she believed that some teachers, such as the female teachers, may have some difficulties in the electricity unit.

แตกต่าง เพราะว่าครูรัฐบาลโดยเฉพาะครูประถมจะจบประถมศึกษาหรือสุศึกษาอย่างนี้ซึ่งไม่ได้จบวิทยาศาสตร์มาโดยตรงก็คือเนื้อหา concept อาจจะทำให้เยอะหนอยและไม่ได้ลงลึก ในรายละเอียดของเนื้อหา มากนักเพราะกลัวครูจะงงไปด้วย เพราะครูเขาไม่ค่อยมีพื้นฐาน เทคนิคการใช้อุปกรณ์นี่ก็จะต้องแนะนำด้วยแต่ถ้าครูเอกชนเขาเลือกสรรคนได้เขาเลือกรับครูวิทยาศาสตร์เขาอาจจะเลือกครูจบวิทยาศาสตร์เขามีพื้นฐานมาบ้างแล้ว บางอย่างเขาอาจจะรู้แล้วก็ได้เราอาจจะช่วยในสิ่งที่คิดว่าบางอย่างเขาอาจจะลืมไป

Private school teachers and public school teachers are different. Most public school teachers graduated in other areas that are not related to science, such as primary education or health education. So, I will give more content knowledge to the public school teachers than the private school teachers who already have good science knowledge. But, I won't give the content in depth because it may confuse teachers because they don't have solid background. (Vimon, Interview #1)

ส่วนมากก็ไม่ยากดูแล้วครูเขามีพื้นฐานอยู่แล้ว แต่ว่าเท่าที่ดูคิดว่าเขาคงเข้าใจครูเขาทำกิจกรรมได้ เท่าที่ดู

I don't think these teachers [private school teachers] will have any difficulties about the concepts because they have good background. Based on my observation during the PD, I think they understand it because they are able to do activity. (Vimon, Interview #2)

The second excerpt demonstrates Vimon's belief that she related teacher's ability in doing activity to the understanding of content knowledge. In other words, Vimon illustrated that teachers would have accurate understanding of the science concepts when they were able to perform activity.

According to her knowledge of areas of teacher difficulty, Vimon demonstrated that teachers exhibited a particular misconception in magnetism and have learning difficulties in electricity concepts.

ครูมี Misconception แน่นอนนี้มันเป็นงานเด็ก ๆ เหมือนผ้าขาวเขาไม่รู้อะไรเลยตรงนี้มันอยู่ที่ครู ครูเอาไปบอก ๆ เขา เอาไปใช้ให้เขา ถ้าครู Missed แน่นอนถ่ายทอดให้เด็กที่ต้อง Missed ด้วย ทุกครั้งจะถามว่าแม่เหล็กดูดอะไร ดูได้ว่าเขาตอบว่า ดูดอะไรแสดงว่าครู Missed หมดเลย

I believe that teachers have misconceptions because students are like a white cloth. They don't know anything. But, teachers transmit their misconceptions to students which lead students to understand the concept in the same way as their teachers. For example, teachers showed their misconception when they said magnets attract to all metals. (Vimon, Interview #2)

However, she seemed to have limited knowledge for helping teachers to overcome these difficulties. For example, when asking Vimom in what way she could help teachers to correct their misconception, Vimom indicated that she could provide hands-on experiences and accurate answers for them. However, it depended on teacher themselves whether or not they would believe in the activity results and her explanation.

เพราะว่าเค้าได้เห็นจริงๆ เพราะว่าถ้าเกิดไปบอกเลยแล้วเค้าเชื่ออย่างนั้นแล้วการที่ไปบอกให้เค้าเปลี่ยนเลยนะมันยาก แต่เราแสดงให้เห็นว่ามันไม่ใช่ ในเมื่อทำการทดลองได้ลองทำด้วยตัวเอง เกิดการเรียนรู้ด้วยตัวเองแล้ว แล้วยังไม่เปลี่ยนความคิดอันนี้คือ คือว่าเป็นอะไรที่คงแก้ไม่ได้แล้วคงแก้ยาก ตัวเองต้องยอมรับ ได้ลองได้เห็นจริงแล้วไม่เชื่อแสดงว่าอัดดาตัวเองสูงก็ฉันจะเชื่ออย่างนี้ (อ. สุภาภรณ์_#2interview)

Because they have real experience, doing the activities themselves and seeing the results so they should believe in what they see. If I tell them directly, they won't change their mind. They need to agree that what they knew is wrong. If they don't, I can't help them. Some teachers have strong ego about what they know is right and is difficult to change. (Vimom, Interview #2)

The excerpt above reveals that Vimom seemed to ignore teachers' misconceptions or struggled for ways to respond to their misconceptions. She demonstrated her limited knowledge of ways to help teachers correct their misconceptions, thinking only of in helping teachers to correct their misconception by supplying more detailed explanation.

In regards to Vimom's case, it reveals that although professional developer realized possible teachers' misconceptions, it does not guarantee the ability to respond effectively during instruction.

Knowledge of PD strategies. Vimom indicated that she used *inquiry* as her PD strategy. When probed on her understanding about inquiry, Vimom stated that:

Inquiry ก็คือกระบวนการนำเสนอกระบวนการสอนอย่างหนึ่งที่มีลำดับขั้นตอนการนำเสนอที่มีลำดับขั้นชัดเจนขั้นแรกก็คือเราความสนใจเด็กให้เด็กเกิดความสงสัยอยากรู้อยากเรียนอยากหาคำตอบขั้นที่ 2, 3 จริงๆ ทุกขั้นมันไม่ได้แยกกันชัดเจนขั้นต่อไปเขาก็ได้ทดลองเพื่อหาคำตอบของเขาเองเพราะการที่เขาได้ทดลองหาคำตอบเองเป็นสิ่งที่เขาก็จะจำได้มากกว่าที่ครูไปบอกเมื่อ เขาได้คำตอบแล้วเขาก็อยากรนำเสนอสิ่งที่เขาเรียนรู้ก็ให้เขานำเสนอให้เขาได้พูดไปโดยที่ครูยังไม่จำเป็นต้องไปบอกว่าสิ่งที่เขาพูดมาผิดหรือถูกอะไรแค่ไหน แต่ครูจะมาทำในขั้นที่ 4 คือที่เขาพูดมาแล้วอะไรที่ยังเป็นความเข้าใจไม่ถูกต้องครูก็ช่วยแนะนำช่วยบอกว่าอันนี้เป็นอย่างนี้นะแล้วครูก็เป็นคนสรุปช่วยสรุปให้อีกทีหนึ่งว่าสิ่งที่

เค้าเรียนรู้วันนี้หลักๆ แล้วมันคืออะไร concept คืออะไร อะไรถูกต้องไม่ถูกต้องสิ่งที่เขาเรียนรู้มันเชื่อมโยงกับชีวิตจริงยังไงชีวิตประจำวัน หรือสิ่งที่อยู่รอบตัวเขาอย่างไรบ้าง ชั้นสุดท้ายขั้นของการประเมิน ที่จริงขั้นของการประเมินมันน่าจะแทรกอยู่ทุกขั้นตอนของการเรียนรู้มันไม่ควรจะแยกแต่การประเมินในที่นี้เข้าใจว่าเขาคงหมายถึงการทดสอบหลังจากจบ section หนึ่งก่อนแต่ถ้าปัจจุบันนี้เขาก็อยากให้เป็น Authentic Assessment การประเมินตามสภาพจริงสังเกตว่าเด็กทำกิจกรรมยังไงเขาสนใจไม่สนใจแค่ไหน แต่มันก็จะไปเพิ่มภาระให้ครูมากขึ้นครูคนเดียวต้องสังเกตเด็กทั้งหมด

Inquiry is a teaching process that includes steps in a clear order, including engagement, exploration, explanation, elaboration, and evaluation.

Students will take responsibility in the first three steps of inquiry when teachers will take responsibility in the second last steps. For elaboration, the teacher will provide correct explanation. For evaluation, now we try to encourage authentic assessment to teachers. However, I think it will increase teachers' workload.

Vimon exhibited an activity-driven orientation to PD which linked to her use of PD strategies. For example, Vimon's goal for PD was to introduce hands-on activities to teachers and provide suggestions about ideas and methods in duplicating manipulative.

Vimon only used the first two steps in the 5E learning cycle. She explained that:

อันที่จริงพยายามจะอิง Inquiry แต่บางที่ก็คงไม่ได้ ได้แค่ตอนแรก ๆ ที่นำเข้ามาทเรียน การเร้าความสนใจหลังจากนั้นก็เป็นการแนะนำมากกว่า เป็นการแนะนำว่าน่าจะทำอย่างนั้นะ บางทีก็ทำให้ดูแล้วเขาก็ทำ ก็เห็นด้วย กิจกรรมแทนที่จะสอนธรรมดา เอ ทำอย่างนี้ให้เด็ก เขาเล่นอย่างนี้ดีไหม อย่างนี้คะ เทคนิคการสอนเราก็จะเป็นอย่างนี้ แล้วก็มีการใช้ ICT นิดหนึ่ง ก็คือตัวเกมส์เข้ามาช่วย

I try to use the inquiry method, but I will only use the first two steps of inquiry including engagement and exploration. After that, I will suggest ideas, techniques, activities, or other electronic tools like games or animations to teachers. (Vimon, Interview #2)

Vimon used engagement technique because she wanted to call attention to teachers before she started introducing activities.

ครูก็เหมือนเด็ก ถ้าเราโชว์กิจกรรมหรืออะไรที่ตื่นเต้น สมมติเราเล่นกลทุกคนจะชอบ จะสนใจ เรียกความสนใจเค้าได้เค้าก็จะตั้งใจฟังอยากรู้

Teachers and students are alike. If we show exciting games or activities or playing magic, they will like it and pay more attention. They want to know how I do it because they want to use this with their students, too. (Vimon, Interview #2)

Although Vimon could describe the phases in the 5E model of instruction, she did not exhibit her ability to demonstrate this strategy and its phases effectively, which led to

questions about whether or not she had adequate understanding about this teaching strategy.

Furthermore, during the interview and observation, Vimom seemed to have limited knowledge of topic-specific strategies in that she did not demonstrate knowledge of ways to represent the concepts that she taught in order to facilitate teachers' learning of the concepts or address their misconceptions even though increasing teachers' content knowledge was not her goals for this PD. In addition, she seemed to hesitate in helping teachers increase their content knowledge. She indicated that:

การให้ความรู้เยอะบางที่ครูรู้แล้วเขามีพื้นฐานแล้วเขาก็ไม่ค่อยสนใจ แล้วบางที่เขาแกลังถามลองภูมิเรตด้วยซ้ำ อย่างน้อยเขามาอบรมทางนี้ เพราะว่าเขาได้ใช้ทำงานตรงนี้ เขาก็คงได้มีความรู้พื้นฐานมาบ้างเรบอกคร่าว ๆ ว่ากิจกรรมนี้สำหรับใช้สอน Concept เรื่องนี้แต่เราไม่ได้มุ่งเน้นหวังที่จะสอนตัว Concept นี้กับครู แต่ว่าการใช้อุปกรณ์บางอย่างที่เขาอ่านได้ แต่บางที่เขาอาจจะใช้ไม่ค่อยถูก เราก็เลยพยายามจะเน้นตรงนั้นและบางที่การสอนเขาไม่มีสื่อที่จะเอาสอนเพราะว่าเขาหาสื่อไม่ได้ เค้านอกสื่อราคาแพง เราก็พยายามจะแนะนำวิธีการทำสื่อหาสื่อง่าย ๆ ก็ตรงกับความต้องการของครู เขานอกเราว่าเขาต้องการอย่างนี้วิธีการผลิตสื่ออย่างง่ายอย่างนี้เลย เขาอยากได้ตัวอย่างสื่อเยอะ เขาอยากได้แบบนี้
If I give knowledge to teachers who already know it, they won't pay attention. Sometime I feel like they try to test my knowledge. So, I decide to suggest the activities to them instead of giving knowledge to them. I will tell them this activity will introduce what concept. Or, what materials they can use instead of the materials that are shown in a book. I give the ideas for teachers about how to reduce the budget by introducing alternative instructional tools. (Vimom, Interview #2)

Knowledge of PD curriculum. Vimom mentioned that the PD curriculum was developed by each professional developer selected some activities from the IPST Curriculum.

เอามาจากหนังสือเรียนดึงเอามาจากหนังสือเรียนมี sheet เสริมบ้างในบางกิจกรรมซึ่งเราออกแบบมาใหม่มันก็คือ concept เดิมที่เป็นเหมือนกิจกรรมทางเลือก ถ้ามาจากหนังสือเรียน โรงเรียนนี้อาจจะไม่พอก็ได้มีกิจกรรมทางเลือกให้ กิจกรรมทางเลือกเราอาจจะต้องให้เนื้อหาเพิ่ม อย่างกิจกรรม electrophorus นี้เราเพิ่มมาทีหลังเราก็ทำใบกิจกรรมเพิ่มให้
I selected activities from the IPST Curriculum. I made some extra activity worksheets or handouts for teachers about the methods in duplicating manipulatives. (Vimom, Interview #2)

Vimon mentioned that this PD curriculum would help teachers know how to set up their science classroom and activities when they were back to the classroom. When asked to talk about the PD curriculum that she used, Vimon indicated that she wanted to revise the curriculum for the next PD to provide clear steps of activities in order to help teachers who did not have solid knowledge to be able to follow the directions. She also wanted to add a section about alternative ideas and activities in the curriculum to provide more choices in selecting activities for students.

ถ้าเรามีการทำเขียนให้ละเอียด ให้ดี เพราะอย่างครูบางคนเขาอาจจะพื้นฐานน้อย อาจจะอ่านแล้วเข้าใจยากสักหน่อย เขียนเป็น step เป็นขั้นๆ แต่ที่เราเขียนแค่อุปกรณ์นี้หลักการทำงานมันเป็นอย่างนั้นๆ ก็แค่เป็นแนวคิดจะทำต่อหรือใช้อย่างอื่นแทนได้ไหม
I think I may revise the PD curriculum in the way that provides clear steps for teachers because some teachers do not have good content knowledge and laboratory skills. If we write it clearly, these teachers can follow it easily. I will also add a section about alternative ideas, activities, or materials so teachers can have choices in making decision. (Vimon, Interview #2)

Knowledge of assessment of scientific literacy. Vimon indicated that she used authentic assessment during her PD session in order to assess teachers' learning. Like other professional developers, Vimon used discussion and observation of teachers doing activities to inform her whether teachers learned something.

ที่จริงมันไม่จำเป็นจะต้องมานั่งวัดการวัดผลมันไม่ใช่การเรียนแล้วสอบ วัดผลเดี๋ยวนั้นมันก็วัดตามสภาพจริง ใช้วิธีดูจากที่เขาทำกิจกรรมแล้วมันทำได้หรือเปล่าอย่างนั้นมันก็เป็น การวัดผล เพราะฉะนั้นผู้สอนทุกคนเขามีการวัดผลตลอด เขาวัดว่าพูดไปแล้วผู้เรียนตั้งใจฟังไหม ผู้เรียนมีการตอบสนองไหมอะไรอย่างนี้ มันก็ถือเป็นการวัดความเข้าใจของผู้เรียน วัดหลายอย่างวัดเจตคติได้ด้วย มันเป็นการวัดผลที่อยู่ในการเรียนการสอน เพียงแต่ว่ามันจะไม่ได้ในเรื่องการวัดผลความรู้ของครู แต่มันก็ไม่ใช่จุดประสงค์หลักของเราแต่แรกอยู่แล้ว เราไม่สอนให้เขาได้ความรู้อย่างเดียวอยู่แล้ว
Now we emphasize using authentic assessment to assess student learning. This assessment method may not assess the teachers' content knowledge, which isn't our goal neither. We use authentic assessment by observing whether teachers pay attention to activity, listening to us, showing any responses, and their attitude. This method is integrated into teaching process. (Vimon, Interview #2)

However, the questions that Vimon used with teachers were mostly close-ended questions. In addition, Vimon did not provide many opportunities for teachers to question or show their thinking. Vimon mostly served a role as explainer of the activity, direction-giver, and information-supplier about the activity. She always ended her explanation by asking teachers whether they understood without waiting for their reply. When asking Vimon how she knew teachers understand science concepts without testing them, Vimon indicated that she did not agree with testing because it gave teachers the idea that they had to test students every time after teaching.

เราไม่ได้เน้นเรื่องการทำข้อสอบมีความรู้สึกว่าการไม่เรียนทุกอย่างต้องทำข้อสอบ เรียนเพื่อทำข้อสอบหรืออะไร แต่เราอยากให้เรียนเพื่อให้เขาเข้าใจ แล้วเอาไปอธิบาย ขยายผล ไม่อยากให้แค่ เดี่ยวเป็นการปลูกฝังให้คิดว่าเรียนจบแล้วก็ต้องทดสอบนะการจะเข้าใจว่าเขาเข้าใจหรือเปล่าไม่จำเป็นต้องทำข้อสอบก็ได้ เช่นการทำกิจกรรมนี้ลองทำแล้วแข่งกันดูก็รู้แล้วว่าทำเป็นไหม ทำได้ไหม

We don't emphasize learning for testing, but learning for understanding. I want teachers to learn something and bring it into their classroom. I don't see the necessities of doing a test. We can use other techniques, such as a racing game. (Vimon, Interview #1)

จากเขาพลิกแผงวงจรที่เราให้ทำ จากเราวาดรูปวงจรแค่นี้ เขาลองทำต่อวงจร แม่เหล็กไฟฟ้าในะกลุ่มไหนจะดูดคลิปแม่เหล็กได้มากที่สุด เขาบอกจะลองเอาลวดพันมา กรอบน้อยรอบหรือว่าเพิ่มจำนวนถ่านไฟฉายหรืออะไรอย่างนี้ แต่เราไม่ได้ให้ดูภาพทั้งหมด บางวงจรเท่านั้นเพราะว่าภาพก็เป็นภาพจากหนังสือเรียนถ้าไม่โชว์หน้าห้องคู่มือเขาก็มี ก็บอกว่าดูจากคู่มือแล้วทำถ้าเขาทำไม่ได้ก็แสดงว่าเขาไม่ได้เรียนรู้อะไรเลยแต่ที่เขาต่อได้ ให้เขาเป็นกลุ่มช่วยกันทำ

If teachers can modify the circuit to have the electrostatic property that it can attract as many paper clips as possible, I think they learned something. Although they might follow the picture or directions in a book, they might not be able to complete it if they don't understand. And when they can do it, that means they learned something. (Vimon, Interview #1)

In order to see whether or not teachers understand the concepts, Vimon noticed teachers' performance doing activity. As Vimon indicated, it teachers could finish activities without any questions, that meant they understand it.

According to the excerpts above, Vimon had limited knowledge of assessment of teachers' learning. She did not display her knowledge of what aspects of teachers'

learning of the topics she taught were important to assess. Vimon exhibited her belief that if the teachers were able to perform activity, they would develop conceptual understanding. Vimon also had limited knowledge of methods of assessment. Although she mentioned authentic assessment, her purpose to employ this assessment strategy was to assess teachers' intention in learning rather than to assess important aspects of their learning and thinking. She indicated that:

วัดผลเดี๋ยวนั้นก็วัดตามสภาพจริงใช้วิธีดูจากที่เขาทำกิจกรรมแล้วมันทำได้หรือเปล่านั้น
นี่มันก็เป็นการวัดผล เพราะฉะนั้นผู้สอนทุกคนเขามีการวัดผลตลอด เขาวัดว่าพูดไปแล้ว
ผู้เรียนตั้งใจฟังไหม ผู้เรียนมีการตอบสนองไหมอะไรอย่างนี้
Now we focus on authentic assessment by observing whether teachers can do activities. So, every professional developer assesses teachers using this technique to see teachers' intention and reflection. (Vimon, Interview #2)

In summary, the data for Vimon reveals that she had limited PCK for PD. Similar to Piti, Vimon believed that teachers already had good understandings of science knowledge necessary to teach primary grades. Although Vimon mentioned about teachers' misconception on magnets, she did not have appropriate knowledge for helping teachers to overcome those difficulties. In addition, Vimon believed that teachers' learning occurs when they are able to perform activities. Vimon's understanding of the 5E model was similar to Piti. She held a misunderstanding of the elaboration steps of the 5E in terms of teachers' and student's roles and learning goals for this step. Similar to other professional developers, Vimon did not explicitly show her understanding of the IPST curriculum. Although Vimon indicated that she used authentic assessment during the PD, she only used questioning and observing teachers during the PD activities. Vimon used these methods in order to check teachers' attention rather than teachers' understanding of the concepts. Finally, Vimon did not agree with providing pre- and post

testing for teachers during the PD. She believed this assessment method would develop misunderstanding among teachers about teaching to the test.

Somsri's Implementation, Orientation, and PCK for Professional Development

PD Implementation

Somsri saw herself as helping the teachers enhance their science teaching methods, content knowledge and, activity management. Somsri indicated that her job was to help teachers solve the problems they might have in the classroom. Similar to other professional developers, Somsri indicated that the chemistry content at the elementary level was easy. She did not think the teachers would have any difficulties either in learning or teaching the chemistry content for elementary grades.

During the PD implementation, Somsri started her session by introducing all chemistry concepts for primary students. These concepts were in the IPST Curriculum. Somsri explained to the teachers about the purposes and content of each concept that primary students were expected to learn. There are many chemistry concepts in the primary level. However, Somsri worked with Peter to select some activities that covered particular topics for this PD. Those topics were material and matter, properties of material such as heat conduction and toughness, states of matter and its properties, dissolution, and chemical changes. Teachers did one activity for each concept. Somsri indicated that her criteria in selecting the PD activities and concepts were 1) reasonable time limit in which they could finish the activities and, 2) availability of activity materials. Somsri mentioned that she removed some activities that would take a long time to observe, such as the separation activity using the suspension method. She also

indicated that activities of the primary levels were easy, which (she thought) the teachers would not have any problems in implementing in their classrooms.

For this PD, Somsri focused on introducing activities in the IPST Curriculum, modeling teaching science using 5E learning cycle model, and helping the teachers to have direct experiences with the activities.

หนึ่งให้ครูได้ศึกษาหลักสูตรที่เราจัดไว้ให้ ทีนี้เมื่อศึกษาหลักสูตรก็ต้องรู้ว่าในหลักสูตรมีกิจกรรมอะไรบ้าง เท่ากับให้ครูได้มาฝึกให้แม่นยำขึ้นก่อนที่จะนำไปสอนเด็กถ้าเขาได้ฝึกและเราได้ชี้แนะในสิ่งที่เค้าควรจะเน้นกับเด็ก เค้าก็จะเกิดความมั่นใจขึ้นนั่นคือประเด็นหลักว่า ได้มาฝึกด้วยตัวของตัวเอง ผิดถูกยังไงเขาจะได้สำรวจตัวของเขาด้วยว่าที่ผ่านมาเขาทำยังไงกับเด็ก เราเพิ่มเติมให้เขา เขาจะได้นำไปเพิ่มกับเด็กหรือไปชี้แนะกับเด็กต่อนั่นคือประเด็นที่หนึ่ง

The purpose is to help them [the teachers] know curriculum. They need to know what activities are in the curriculum before they teach the students. We [professional developers] suggest to them what significant things they need to emphasize to the students. Then they have more confidence to teach because they are trained well. They also have the opportunity to check themselves about what they have done in the past. Our role is to supplement them with additional information so they can do the same thing with the students. (Somsri, Interview #2)

Somsri's other goal was to improve the teachers' lab skills, which would help the activities work. Somsri indicated that the majority of teachers had less experience in labs. Thus, the teachers did not have confidence in implementing science activities with their students. Somsri also mentioned that although she believed that the PD teachers already understood the chemistry concepts they taught at school, she still wanted to explain that content knowledge to the teachers in order to help them recall and confirm their knowledge.

After introducing the curriculum, Somsri modeled the engagement step by asking teachers to fold a strip of paper and a banana leaf. Then, she asked the teachers to explain what the purpose was of this activity. Before doing each activity, Somsri asked the teachers to carefully read the activity instructions in the PD manual before starting the

activities. At the same time, she clearly explained to teachers what they needed to do and observe. For example, during the heat conduction activity, Somsri warned teachers to touch each spoon about 1 centimeter from the end. Rather than encouraging teachers to design their own investigation, Somsri directly told teachers when they should start and stop timing. After the teachers finished each activity, Somsri led the discussion about results and conclusions. She also explained to the teachers what scientific concepts and lab skills they needed to know of each activity. However, at the end of this activity, Somsri reminded teachers to lead the discussion with their students about the activity in terms of its design and limitations. She mentioned to the teachers that although she did not have the teachers design their own experiment, the teachers should encourage the students to do it. In addition, the teachers might be able to use other materials or activities with the students in order to introduce the concept of heat conduction. During the activities, Somsri traveled from group to group and asked questions that checked the accuracy of the teachers' observations and focused the teachers along a path that would lead them to a correct conclusion. She also asked the teachers to hurry, because she was afraid that if the time ran out, the teachers could not do every activity. In addition, Somsri was afraid that she would not have time to provide important information on each concept to the teachers.

ก็อยากจะขอร้องอาจารย์ว่าช่วยกันทำอย่างรวดเร็วแล้วเราจะได้มาคุยรายละเอียดของ
เนื้อหาจากการทดลองอีกครั้งหนึ่ง ถ้าอาจารย์ทำการทดลองซ้ำเราจะไม่มีโอกาสจะบอก
อาจารย์ในสิ่งที่เราอยากจะทำบอก เพราะฉะนั้นอาจารย์ต้องรีบทำกิจกรรม รีบบันทึกผลและ
สรุปกิจกรรมอะไรต่ออะไรไม่อย่างนั้นอาจารย์ทำไปแล้วอาจารย์ก็ไม่ได้มาสรุปผลอาจารย์ก็
ไม่ได้ concept อะไรที่จะไปบอกเด็กนะ

I would like to ask you to hurry in doing activities so we could have time
to talk about the details of activities. Otherwise, I would not have a chance
to tell you about many things that you need to know. So hurry and make
conclusions. Otherwise, you would not know the concepts and you would
not able to talk to your students when you return to your classroom.

(Somsri, During PD Implementation)

Although Somsri modeled the 5E model of instruction to the teachers, she believed that it was not necessary to implement all 5 steps for every science activity. She mentioned that it depended on the content and the nature of the activities. For some activities, it was impossible to implement all 5 steps. Somsri indicated that only some activities that required labs would have all steps. In addition, the observations of her PD implementation and interview revealed that Somsri believed that teachers had an important role in leading students to scientific knowledge. After the end of each activity, the teachers still needed to provide the scientific facts directly to the students.

Orientations

Figure 13 represents my analysis of Somsri's orientations. I found that, during the interviews and PD implementation, Somsri's orientation to PD consisted of four central goals and one peripheral goal. Her central goals were 1) to introduce scientific activities in the IPST curriculum that were aligned with the reform National Science Standards; 2) to develop PD participants' laboratory skills that were necessary to make the activities work; 3) to develop teachers' conceptual understanding of the chemistry concepts that were taught in PD; and 4) to model teaching science through inquiry to the teachers.

เค้าก็จะได้วิธีการสอน ได้เนื้อหา ได้การทำกิจกรรม อาจจะช่วยแก้ปัญหาการทำกิจกรรมให้เขา แล้วก็วิธีสอน เราก็ไม่แน่ใจว่าเขาจะเก่งกว่าเราหรือเปล่าแต่เราก็จะให้เขา วิธีสอน การอภิปราย สรุปผลการทดลอง เทคนิคต่างๆ

Teachers will learn teaching techniques, content knowledge, and practice their performance in doing activities. I will also help them solve some problems that occur during the activities. I'm not sure that they might be better than I thought, but I will give teaching methods, discussion, conclusion, and other techniques to them anyway. (Somsri, Interview #1)

To support these goals, Somsri saw her job as a way to have the PD participants recognize the chemistry concepts that were required to teach for the primary grade level.

She tried to cover many activities in the IPST Curriculum by either explaining directly to the teachers or allowing the teachers to do the investigation.

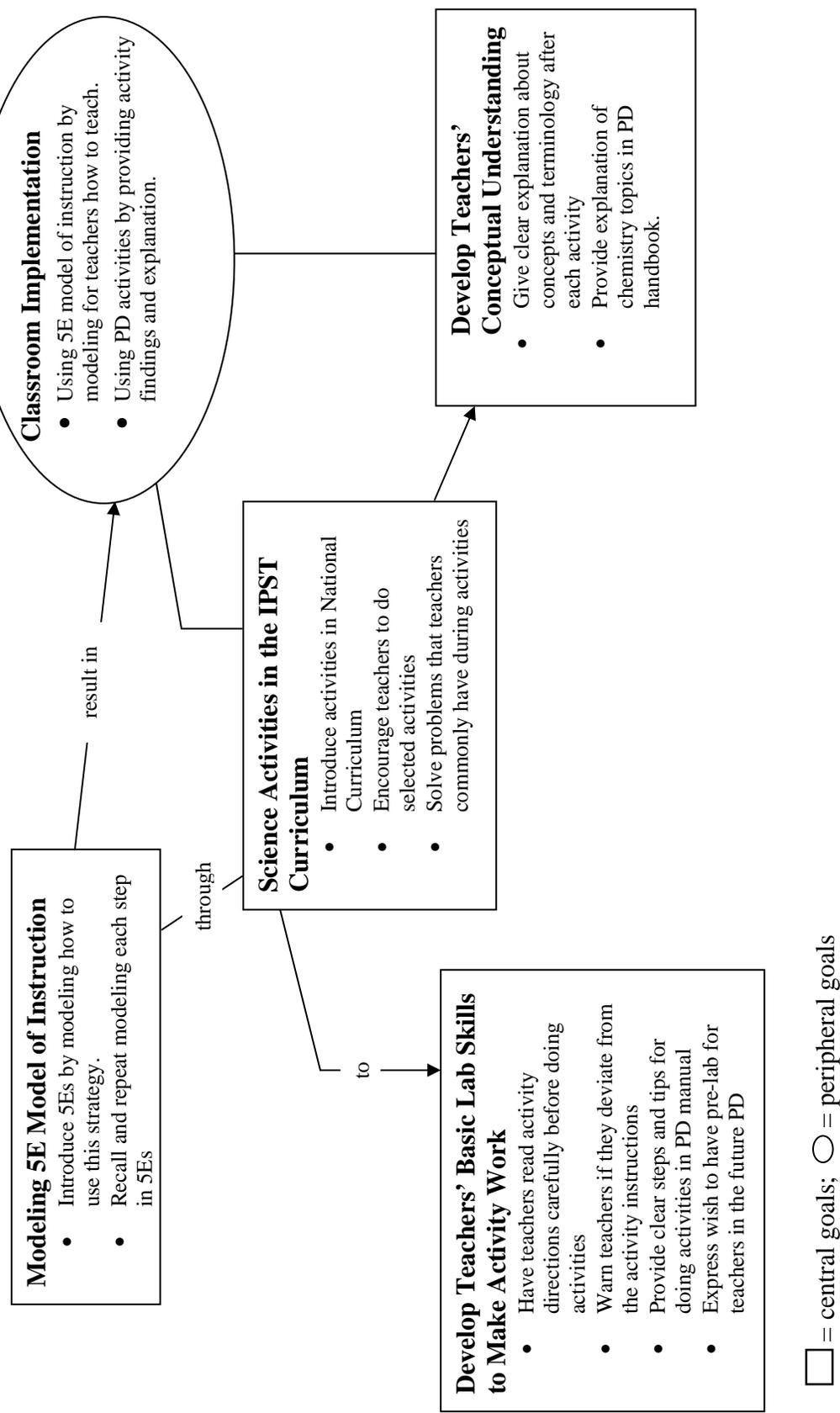
หนึ่งเพื่อให้ครูได้ศึกษาหลักสูตรที่เราจัดไว้ให้ ทีนี้เมื่อศึกษาหลักสูตรก็ต้องรู้ว่าในหลักสูตรมีกิจกรรมอะไรบ้าง เท่ากับให้ครูได้มาฝึกให้แม่นยำขึ้นก่อนที่จะนำไปสอนเด็กถ้าเขาได้ฝึกและเราได้ชี้แนะในสิ่งที่เค้าควรระมัดระวังกับเด็ก เค้าก็จะเกิดความมั่นใจขึ้นนั่นคือประเด็นหลักว่า ได้มาฝึกด้วยตัวของตัวเอง ผิดถูกยังไงเขาจะได้สำรวจตัวของเขาด้วยว่าที่ผ่านมา เขาทำยังไงกับเด็ก เราเพิ่มเติมให้เขา เขาจะได้นำไปเพิ่มกับเด็กหรือไปชี้แนะกับเด็กต่อ นั่นคือประเด็นที่หนึ่ง (อ. อนุรักษ์รวง_#2interview)

I introduced curriculum to teachers such as how it aligns with standards, how many activities there are. I think this way helps teachers have more confidence about the curriculum. I provide opportunities for them to practice activities before they have to teach students. So, they can check themselves whether or not they did it right in the past. I will also suggest necessary knowledge, teaching techniques, so they can do the same things with their students (Somsri, Interview #2).

เราไม่ได้ให้เค้าทำทุกเรื่อง เพราะเวลามันจำกัด แค่นี้ก็ไม่ทันแล้ว แต่เราก็อธิบายให้เค้าทุกเรื่อง อันไหนที่เป็นเทคนิคเราก็เน้นให้เค้าแต่เค้าก็ไม่ได้ลงมือทำ แต่ก็คิดว่าถ้าเค้าลงมือจริงๆ มันก็ทำได้เพราะมันไม่มีอะไรยาก

They [teachers] did not do every activity because we didn't have time. However, I explained either knowledge or techniques of every activity to them although they did not do hands-on activities. But, I think if they had a chance to do it, they could do it anyway because it isn't difficult. (Somsri, Interview #2)

Figure 13. Somsri's Goals for PD



Somsri added that another goal for PD was to help teachers understand the chemistry concepts in grades 1-6. This PD was mixed with teachers who taught 1-3 grade levels and 4-6 grade levels. Somsri mentioned that these teachers needed to understand the curriculum vertically they needed to know what students learned in the previous years and what they would learn in the next grade level. In addition, Somsri indicated that teachers themselves needed to understand 1st to 6th grade curriculum because they might have to teach different grades in the near future.

ครูบางคนไม่เคยสอน บางคนก็สอนแล้ว บางทีสอนช่วงชั้นหนึ่ง แต่ช่วงชั้นสองไม่ได้สอน ครูบางคนสอนช่วงชั้นสอง ช่วงชั้นหนึ่งไม่ได้สอน เพราะฉะนั้นการอบรมนี้ทำให้ครูได้รู้เนื้อหาหรือองค์ความรู้ตลอดหลักสูตรของชั้นประถม นี่เป็นจุดมุ่งหมายอีกอย่างหนึ่งด้วย เพราะคนหนึ่งจะสอนทั้ง 2 ช่วงชั้นน้อย ส่วนมากจะช่วงชั้นใดช่วงชั้นหนึ่ง ทำให้ครูได้รู้ในช่วงชั้นที่เขาไม่รู้ด้วย

Some teachers did not use our curriculum before, some teachers only teach at 1st-3rd grades while some teachers teach 4th-6th grades. But, I think teachers need to know the curriculum along 1st-6th grade in order to understand what students have to learn at these levels and to be able to teach in any grades. (Somsri, Interview #2)

To help teachers to understand about the 5E model of instruction, Somsri used this teaching strategy as her PD strategy. Somsri selected one activity for fully modeling how this teaching approach could be used in science classroom. Like Piti, Somsri reminded teachers about her techniques that she had done at the beginning of the session.

สอน Inquiry ครบทั้ง 5 ขั้น โดยสาขาเค้าให้เราเลือกเองว่าจะเอากิจกรรมไหนมาสาธิต 5E ซึ่งกิจกรรมมันสามารถครอบคลุมเนื้อหา ตั้งแต่ ป1 – ป6 ครอบคลุมได้หมดเลย เราก็ทำให้เค้าดูจากนั้นก็มาเน้นย้ำกับเค้าอีกทีว่าแต่ละขั้นที่เราทำคืออะไร

The department asked us to model teaching science using all 5 steps in inquiry. We were free to decide what activity in what grade that we would use for modeling. So, I modeled for teachers how science should be taught and after that reminded teachers about each step I did. (Somsri, Interview #2)

In order to develop teachers' conceptual understanding, after each activity, Somsri explained the results, conclusions, and scientific knowledge to the PD participants. In

addition to activities, Somsri indicated that she should help teachers develop laboratory skills and techniques that were necessary to do activities.

ส่วนใหญ่เราเน้นให้ความรู้เพื่อให้เค้านำไปสอนเด็ก เราก็ต้องให้ทำกิจกรรมในหนังสือเรียน ก่อนที่จะไปสอนเด็กเพื่อให้เกิดความมั่นใจ แล้วเราค่อยมาเพิ่มเติมเนื้อหา ความรู้แล้วก็ เทคนิคต่างๆ ให้เค้าอีกที

My emphasis is to give teachers knowledge that they have to teach. I had teachers do the same activity as in the curriculum they use at school in order to help them have more confidence. After that I provided content knowledge, teaching techniques, and lab techniques that they need to know. (Somsri, Card Sort Activity)

เพราะเราไม่ได้ pre lab เขาเพราะเห็นเขาเป็นครูแล้ว ถ้าเราสอนเด็กเราต้อง pre lab ไม่อย่างนั้นจะไม่รู้ว่าต้องสังเกตอะไรใจอยากจะทำ pre lab กับเขาก่อนด้วยซ้ำ ที่นี้เราก็กังลังเลอยู่ว่ามันเหมาะสมไหม ที่จะมา pre lab กับเขาคณะระดับนี้ ไม่ใช่เด็กนะ ถ้า pre lab มากไป ก็เหมือนเราชื่อนามากไป อยากให้เกิดจากเขา ให้เขาค้นพบเอง แต่ปรากฏว่าบางคน ก็พบเอง บางคนก็ไม่พบ เพราะฉะนั้นถ้าจะแก้จริงๆ โดยไม่ต้องถือว่าเขาระดับไหน เพื่อให้ได้ผลถูกต้อง สังเกตได้ครบถ้วน ควรจะ pre lab ก่อน

I wish I could provide pre-lab to teachers. But, I didn't because I thought it might not be appropriate since they are teachers and it might be too much guidance. I want them to figure out on their own, but only some of them can do that while many of them don't know what to observe. I think the solution is to provide pre-lab to them no matter if they are teachers or students. (Somsri, Interview #2)

Somsri, as a professional developer, also determined her role in providing guidance to the teachers before they started doing activities. The teachers needed to know what to observe, how to conduct the activities, when to start measuring, and explanations for those activities.

หยดแอมโมเนียหอมมันก็ได้ผลนะ แต่ว่ามันควรจะเพิ่มจำนวนหยด เพื่อให้เห็นสีชัดเจนกว่านั้น ซึ่งที่แรกก็จะบอกเขาเหมือนกัน แต่ก็ไม่ได้บอกว่าจะใช้จำนวนหยดมากกว่านั้น แต่มันก็เห็นสี แล้วเราบอกให้คน ครูเขาก็ไม่คน เขาก็แค่หยดเห็นสีเขาก็จบ เขาไม่ค่อยละเอียดที่จะทำตามที่เราบอกไว้ แต่มันก็เห็นผล แล้วก็การสังเกตของครูเขาก็ไม่ค่อยละเอียดเท่าไร เขาก็มองเห็นแต่สิ่งที่มันชัด แต่ว่าลึก ๆ กว่านั้นเขาไม่ค่อยสังเกตเช่น สีเปลี่ยนเป็นสีน้ำเงิน แต่เค้าไม่พูดถึงว่ามีตะกอนด้วยนะ เขาไม่สังเกตละเอียด เขาไม่สังเกตว่าสีเปลี่ยนจากฟ้าเป็นสีน้ำเงินก็จบ เราไม่ได้ย้ำ เราต้องการจะทดสอบความคิดของเขา ว่าเขาจะคิดยังไงเขาก็ใช้ บีกเกอร์ใหญ่บ้างเล็กบ้าง แล้วก็การผสมป้อนเนี่ยเขาก็คนๆ บอกให้คนก็คน เขาไม่รู้อะไรจะสังเกตอะไรนอกจากกลิ่นจะมาปะทะเขาเองบอกให้ดมรู้สึกเราไม่บอก ผสมให้เข้ากัน แล้วก็สังเกต เขาก็หนึ่งภาชนะมันจะต้องเขียนลง เขาก็แทบไม่ค่อยได้สังเกต จนเรามาเน้นเขาต้องจับ กลิ่น ต้องสังเกตทันทีถ้ามันจะหมด ซึ่งจริงๆ เราก็ก่อน Pre-lab ให้เค้าก่อนนะ เค้าจะได้รู้ว่าจะต้องทำอะไรยังไง

For example the ammonium hydroxide activity, teachers did not have ideas about how many drops they should put into the test-tube and when they dropped it, then it's done. They did not stir or observe carefully what

else happened excluding changing color. I did not emphasize this because I wanted to see their ideas. But, if we did not tell them, they wouldn't do anything. Finally, I had to tell them what they needed to observe, what would happen, and why. I think providing pre-lab to teachers might be a good idea, so they would know what to do. (Somsri, Interview #2)

To help teachers improve their laboratory skills, Somsri orally explained to teachers about the activities, and asked teachers to read and followed the activity directions while they were doing activity. Somsri warned teachers when she noticed teachers deviate from the activity directions.

บางทีครูเขาก็ไม่ได้เน้นย้ำเด็ก เราก็เตือนครูว่าอย่างนี้ต้องเน้นเด็กนะ ต้องสอนเด็กนะ เราก็จะเตือนไปในตัวด้วย สิ่งที่ครูทำไม่ถูก เราก็กลัวว่าน่าสิ่งนั้นไปสอนเด็ก เราก็ต้องเตือนที่ถูกมันเป็นยังไง
Sometimes teachers don't emphasize to students, so I have to warn them not to forget teaching their students. Or, when they don't use lab techniques correctly, I will warn them and tell them the right thing. Otherwise, they will teach something that is not correct to students. (Somsri, Interview #2)

Figure 13 also reveals Somsri's peripheral goal, which was to promote classroom implementation using the 5E strategy and PD activities.

อยากให้เค้าเอาวิธีการสอน และกิจกรรม ไปใช้กับนักเรียนในห้องเรียน เราก็ให้ความรู้เค้า แนะนำเทคนิคต่างๆ ให้เค้าเพื่อให้เค้าเอาไปใช้สอนได้อย่างมั่นใจ
I want teachers to use what they learn from PD, such as teaching techniques, and activities with their students at schools. I also provide knowledge and suggest other techniques to them in order to help them teach with confidence. (Somsri, Interview #2)

Somsri's orientation for PD was also displayed when she reflected on the scenarios during the card sort activities. Table 9 shows Somsri's interpretation and arrangement of the card sort scenarios into an order that most represented her PD teaching.

Table 9

Somsri's Arrangement and Interpretation of the Card-Sort Scenarios

Items	Scenarios	Somsri's Interpretations
10	You, as a professional developer, have teachers first engage in laboratory activities in a book, class discussion. You will end each activity with your explanation of science knowledge beyond those activities. (didactic)	"This scenario is similar to my teaching. We will provide opportunity for teachers to discuss, but we have to provide correct knowledge to them at the end of the activity." (didactic)
4	When doing laboratory activities, you provide teachers with clear, easy following, step-by-step directions for the activity procedure. Every activity was in the National Curriculum. You also provide the teachers with materials to help them implement the activities at their classrooms. (activity-driven)	"I employ the same strategies stated in this scenario, except I don't give materials for teachers to take to school. They have to find their own." (activity-driven)
8	You, as a professional developer, design a PD lesson on dissolution by encouraging teachers to do activities that their students would do. At the end of session, you assign teachers to discuss within their group, then as a whole about what they learn about dissolution and about teaching this unit. (reflective)	"Because we want them to implement the activities with their students when they go back to school. The activities that teachers do in the PD are in the curriculum that teachers have to teach. Then, PD provides opportunities for them to practice those activities." (activity-driven)
2	You, as a professional developer, begin a unit of electricity by having teachers talk about their ideas about electricity. Then you allow teachers to work with a particular circuit and develop their own explanations. You show the scientists' ideas about electricity and encourage teachers to discuss and compare how their ideas are different to the scientists. (conceptual change)	Actually, this scenario is too broad. Maybe I am not an expert in physics, but I think it's too broad. However, we use this strategy in the PD, except comparing ideas with scientists. I don't do that and don't understand why it is needed. If this sentence means compare teachers' findings with scientific theory, I do that. I give teachers the correct answer of the findings and provide explanations. (didactic)
9	You, as a professional developer, begin a unit on sound by introducing curriculum, explaining materials, allowing teachers doing activities, and you explaining the concepts at the end of activities. (didactic)	For my session, I introduced and explained the framework of the Chemistry concepts that are in the Standards, and then told teachers what they had to do in this session, and then allowed them to do activities following the directions in a book. (didactic)
3	You, as a professional developer, set up PD lessons for a unit on heat conduction. You introduce heat conduction activities for a 6 th grade elementary book. You select a variety of fun, and easy-to-do activities for PD. (activity-driven)	During the implementation, I told them that rather than the activity they did on that day, they still had other activities that introduced the same concept. They can decide which activity would be better for their students. Actually, if we had more time, I would have them do many kinds of activities. But, it was not possible. Thus, what we could do was to give them suggestions. (activity-driven)

Somsri indicated that the strategies in scenarios 10 and 4 were close to her PD strategies. Somsri reflected on scenario 10 that:

นี่แหละก็ทำแบบนี้ล่ะ เราให้ครูเค้าได้ทำกิจกรรม ให้เค้าได้เห็นได้สัมผัสของจริงก่อน จากนั้นให้เค้าได้สนทนากันในกลุ่มซึ่งตรงนี้ไม่ต้องบอกเค้าหรอก มันเกิดเองโดยอัตโนมัติ แล้วเราค่อยมาอภิปรายกันในกลุ่มใหญ่อีกทีโดยวิทยากรนำเสนอ นำอภิปรายพร้อมทั้งแทรกความรู้ไปด้วย

I do the same way stated in this scenario. I have teachers to do activities in order to help them have hands-on experience. Then, I encourage them to discuss within their groups. Actually this phenomenon occurs automatically without telling them. Then, I encourage them to discuss as a big group when I lead them to the conclusion and discussion of the activities. Then, I provide the explanation and knowledge for those activities. (Somsri, Card Sort Activity)

According to Table 9, Somsri's reflection on each scenario was quite consistent with her implementation: teachers would be engaged in hands-on activities and be provided activity findings and content knowledge. At the end of the activity, Somsri led teachers to come up with the conclusions of the activities. Somsri also provided content knowledge that she felt was necessary for teachers to teach at school, and also other teaching techniques that they needed to know. Somsri's reflection on scenario 9 corresponds with the beginning of her session, when she introduced the curriculum to the teachers in order to help them understand the framework and objectives of the activities in the curriculum. She preferred teachers to perform activities following the activity directions rather than challenging them to design and carry out their own investigations.

ก่อนที่เราจะอบรมเราก็ต้องแนะนำขอบข่ายของหลักสูตรว่ามีอะไรบ้าง แล้วต่อไปเราจะต้องทำอะไรบ้าง หลังจากนั้นให้เค้าดำเนินการทดลองตามหนังสือเรียน เพราะอุปกรณ์เค้าก็มีอยู่แล้ว

For my session, I introduced and explained the framework of the Chemistry concepts that are in Standards, and then told teachers what they had to do in this session, and then allowed them to do activities following the directions in a book. (Somsri, Card Sort Activity)

Somsri's orientations were a combination of didactic, activity-driven, and pedagogy-driven orientations. Somsri strongly exhibited the didactic orientation. For

example, although she allowed the teachers to explore many activities, she always provided the explanation of activities and scientific knowledge to the teachers rather than provide opportunities for the teachers to construct and communicate their own explanations. She led the discussion with teachers in order to provide them with the correct activity results, conclusions, and knowledge of the concepts that were taught. Somsri held a didactic-driven orientation, as seen when she rushed the teachers in doing activities. Somsri also asked the teachers to follow the activity instructions in the activity manual strictly.

การเปลี่ยนแปลงทางเคมี ปัญหาก็คือครูเขาไม่ค่อยได้อ่านวิธีทดลองอย่างละเอียด ครูเขาก็จะหละหลวมไปในบางบางเรื่อง อย่างเช่น เรื่องแก๊สก็ไม่มีปัญหานั้น ชัดเจนอย่างเช่น หยดแอมโมเนียหิมมันก็ได้ผลนะ แต่ว่ามันควรจะเพิ่มจำนวนหยด เพื่อให้เห็นสีชัดเจนกว่านั้น ซึ่งที่แรกก็จะบอกเขาเหมือนกัน แต่ก็ไม่ได้บอกว่าจะใช้จำนวนหยดมากกว่านั้น แต่มันก็เห็นสี แล้วเราบอกให้คน ครูเขาก็ไม่คน เขาก็แค่หยดเห็นสีเขาก็จบ เขาไม่ค่อยละเอียดที่จะทำตามที่เราบอกไว้

I had problems during the teaching of chemical change because teachers did not read the directions closely. So, they did not make observations carefully without my guidance. (Somsri, Interview #2)

This claim was also supported with the card sort activity when Somsri agreed with scenario 10. This scenario indicated that after the teachers did the activities, the professional developers provide explanations. Somsri's reflection on scenario 2 also confirmed her didactic orientation. She did not agree with scenario 2 at the beginning because to have the teachers share their own experience about electricity without leading questions was too broad. She explained that they (the professional developers) should be more specific about what "we want them to talk about" (Somsri, Card Sort Activity). She also mentioned that she did not like the statement at the end of the scenario that had the teachers compare their own explanations with the scientists. Somsri indicated that she already informed the teachers of the correct science concepts and scientific theories.

มันติดตรงที่นำเสนอความรู้ที่พบโดยนักวิทยาศาสตร์นี้แหละ ก็ถูกเวลาเราสอนเราก็ให้ทำกิจกรรม เราก็ให้มีการอภิปราย อธิบายแล้วก็ให้ความรู้เพิ่มเติม ไข่เราต้องทำอย่างนั้น แล้วที่นี้เปรียบเทียบความรู้ของตนกับของนักวิทยาศาสตร์มันเป็นยังไง หมายความว่าผลของเค้าที่ได้กับทฤษฎีไข่ม้อย อันนี้เราก็ต้องอภิปรายอยู่แล้วว่าผลของเค้าออกมาตรงหรือไม่ตรง ถูกหรือผิด เราก็ต้องมีการชี้แจง มีการอธิบายอยู่แล้ว

I don't do that and don't understand why teachers need to compare their finding with the scientists. If this sentence means compare teachers' findings with scientific theory, I do that. I give teachers the correct findings and provide explanation. (Somsri, Card Sort Activity)

However, she agreed with the strategies in scenario 2 that required the teachers to discuss specific questions, do activities, discuss their results, and be provided with the correct responses at the end of each activity.

Somsri slightly displayed an activity-driven orientation. During the PD implementation, she would try her best to cover all of the activities that she prepared for the PD, especially at the end of the session, rather than focusing on the teachers' understanding of the activities or the scientific concepts. Although Somsri provided content knowledge of each activity to teachers, she did not know whether or not teachers understood her explanations.

เราก็พยายามให้เขา แต่เราก็ไม่แน่ใจว่าครูเขาจะเข้าใจถูกต้องไหม เราก็เลยย้ำเขาโดยแยกให้เขาเห็น ให้ได้ concept ให้มากที่สุด แต่ก็ไม่รู้ว่าจะได้แค่ไหนนะ

I try to give correct knowledge to them as much as I can. However, I'm not sure whether they understand it in the way that I want them to understand. I try to make each concept clear for them. (Somsri, Interview #2)

กิจกรรมก็ไม่ได้ลดเพียงแต่ที่เราจะควบคุมเวลาของเราให้เร็วขึ้นหรืออะไรเพื่อให้มันทันเวลา อย่างเช่นครูเขาทดลองซ้ำเราก็จะพยายามกระตุ้นเขาเพื่อให้ทัน แล้วเราก็รีบอธิบายเค้า

I don't reduce the number of activities. Instead, I control the timeframe by rushing teachers to hurry finishing the activities and I will quickly provide explanations. (Somsri, Interview #1)

In line with the pedagogy-driven orientation, during the PD implementation Somsri encouraged the teachers to relate their direct experiences as learners in the PD to the pedagogical strategy that they might use in the classroom. Somsri frequently

informed the teachers which element she believed was important and should be emphasized to the students. However, Somsri indicated that she did not agree that professional developers had to model teaching science using the 5E model of instruction because it was wasted time and caused her to rush teachers at the end of the session.

แต่ที่นี้ถ้าจะแสดงการสอนให้ครบทุกขั้นตอน ซึ่งคราวก่อน ๆ ไม่ได้แสดงกันขนาดนี้ แต่คราวนี้อาจจะแสดงจนครบ ก็เลยทำให้เสียเวลา เพราะฉะนั้นคิดว่า คราวหน้าถ้าจะอบรมใหม่ คิดว่าเราไม่ต้องเอาให้ครบชั้นแล้ว มันไปทำให้เนื้อหาส่วนหลังที่มันสำคัญกว่า มันเสียเวลาไป เพราะคราวน่าคิดว่าจะต้องลด ให้เขาทำนิดหน่อย แต่ไม่ต้องครบทุกขั้นตอน คิดว่ามันจะช่วยให้มีเวลาพอสำหรับเรื่องข้างหลัง เพราะเรื่องข้างหลังมันแรงมาก

In this PD, I fully modeled the teaching strategy, which I only partially modeled the strategy in the previous PD. I think it wasted time, I couldn't have teachers finish all activities that I expected them to do. I think, I won't have teachers participate in every phase like this PD. So, I will have enough time for the activities at the end. (Somsri, Interview #2)

Somsri indicated that she might not fully model the 5E teaching strategy in future PD projects. According to the excerpt, Somsri did not have as strong a pedagogy-driven orientation as compared to Piti.

In summary, Somsri held multiple orientations, a similar trait she shared with other professional developers. She believed that whether or not the teachers understood the concepts before participating in the PD, her role was to instruct or re-enforce content knowledge, which included science knowledge, teaching knowledge, or knowledge in doing laboratory activity. Because of the time constraint, Somsri indicated that professional developers should have the teachers do the activities that introduce important and difficult concepts. In order to save time, the professional developers could directly describe to the teachers the fundamental science concepts rather than having them to engage in an activity.

PCK for PD

Knowledge of teachers' understanding of science. Somsri exhibited that she did not know much about the PD participants, such as educational backgrounds, perceived needs, or their problems at schools. She indicated that:

ปัญหาของเขาเราก็ไม่ทราบเพียงแต่ว่าที่เราเห็นจากครูประถม แต่ที่นี้ของ สข. เราก็ไม่ทราบว่าเค้ามีปัญหาตรงกับครูประถมของรัฐหรือเปล่า แต่ที่นี้เราก็ assumeว่าเขาอาจจะมีปัญหาเหมือนกันเราก็ไม่รู้ว่าคุณครูเขาสูงกว่าโรงเรียนรัฐบาลหรือเปล่านั้นเราก็ไม่รู้ ถ้าเขาสูงกว่าเขาอาจจะมีความรู้มากกว่าแต่ถ้าโรงเรียนรัฐบาลส่วนใหญ่เขาก็ไม่ค่อยออกวิทยาศาสตร์เขาก็ไม่ได้เรียนวิชาเอกวิทยาศาสตร์ เพราะฉะนั้น content อะไรเขาก็ไม่ค่อยจะเป็นสรุปอะไรก็ไม่น่าจะเป็นทำการทดลอง เทคนิคต่างๆ ก็ไม่ ค่อยจะเป็นเท่าไหน และเครื่องมือต่างๆ

I don't know their problems, what they need because they are from private schools, which I am not familiar with. But, I assume that they have the same problems as the public school teachers in that those teachers do not have science education background. Thus, they don't have solid content knowledge, which leads to inability in doing an activity, making conclusions and explanations. They may not know about the teaching techniques and laboratory skills either. (Somsri, Interview #1)

According to the excerpt, Somsri did not have information about teachers' needs for learning a particular chemistry topics or knowledge of teachers' abilities and skills.

However, based on her experience working with public school teachers, she assumed that these teachers might have the same problems.

Somsri displayed that her knowledge of areas of teacher difficulties was also limited. She mentioned that the chemistry concepts at primary grades were superficial, and teachers did not need to have knowledge in depth in order to understand these concepts. Somsri explained that teachers should not have any problems with the content knowledge for teaching primary grades. In addition, the activities that IPST designed for primary students were easy to do, and curriculum developers provided clear steps for the activities in a teacher-guided book.

ในหลักสูตรของเราเองนี่นะ ไม่รู้สิเนื้อหาไม่ได้ลึกอะไร ดูเหมือนครูจะเข้าใจ กิจกรรมเพียงยากหรือ ไม่รู้สิ ไม่รู้สิคิดว่ามันยากเพราะกิจกรรมเราก็ง่ายๆนะ

The content knowledge and activities in our curriculum are not difficult. I think teachers seem to understand all of them. (Somsri, Interview #1)

Somsri indicated that in teaching the concept of heat conduction, the difficulties that teachers might have would be knowledge about the kinetic energy. However, this knowledge was already provided in the teacher-guided book.

ในระดับนี้เราก็ไม่ได้พูดอะไรมากเพียงแต่ว่าในคู่มือครูเราจะเขียนไว้ มันเกี่ยวกับเรื่องพลังงานจลน์เหมือนกันอาณาเขตของของแข็งเมื่อได้รับความร้อนแล้วมันจะเคลื่อนที่เร็วมีพลังงานจลน์เพิ่มขึ้นเราไม่ได้ลงในเนื้อหาแต่เขียนไว้ในคู่มือครูเพราะฉะนั้นเราก็ไม่ได้ลงลึก I don't go into details about kinetic energy during the PD, but I tell teachers that they can look at the teacher-guided book. (Somsri, Interview #1)

In addition, Somsri mentioned that the concept of kinetic energy might be too high for the teachers to teach at primary levels. Thus, she preferred to emphasize only the concepts that teachers had to teach.

เนื้อหาที่เราจะอบรมให้ครูนี้ก็จะต้องเท่ากับที่นักเรียนทำ หรือเท่ากับหลักสูตรโรงเรียน ไม่ได้เกินไปกว่านั้น
The content knowledge that I will provide to teachers during the PD will be the same level of knowledge for students. (Somsri, Interview #1)

Knowledge of PD Strategies. Similar to Piti and Vimom, Somsri demonstrated her knowledge that there are 5 steps in inquiry including engagement, exploration, explanation, elaboration, and evaluation. Somsri indicated that she used inquiry as her PD strategy because it provided opportunities for teachers to participate in hands-on activities. This strategy helped teachers to understand the science process and develop laboratory skills when professional developers led teachers to discussion and provided correct knowledge at the end of activities.

เพราะเค้าได้ทำจริง ได้สัมผัส ได้สังเกตโดยการสัมผัสจากของจริงแล้วก็มีคำอธิบายอธิบายประกอบเขาก็น่าจะเข้าใจ วิทยากรนำอภิปรายและอภิปรายร่วมกัน
Because they have real experience by doing the activities, and together with my explanation, I think they will develop knowledge. (Somsri, Interview #1)

เราจะเริ่มแนะนำเนื้อหาในสาระ เคมีก่อน แล้ว แนะนำกรอบว่ากรอบของสาระนี้ใน ระดับประถมนี้เป็นยังไง จากนั้นให้ครูทำกิจกรรมที่มีอยู่ในใบงาน แล้วเราจะมาอธิบายองค์ ความรู้ พร้อมทั้งเน้นย้ำสิ่งที่ครูควรระวัง เช่น เทคนิคการทำ lab หรือว่าการนำไปใช้ใน ห้องเรียน อาจารย์ควรระวังอย่างนี้ เราจะสอดแทรกไปด้วยตลอด ก็คิดว่ามันน่าจะเป็น อย่างนี้ละนะ เรามานั่งคิดอย่างนี้นะ คิดว่าบางที่รายละเอียดที่เราอยากจะให้เขาบางที่ เวลา มันไม่พอ บางที่เราก็อธิบายไปบ้างอะไรอย่างนี้ รายละเอียดเรื่ององค์ความรู้บางอย่างเรา อยากจะพูด แต่บางเราไม่ได้พูด เช่นว่า ทำไมของเหลว และ แก๊ส จึงมีรูปร่าง หรือ ปริมาตร ไม่คงที่เหมือนกับของแข็ง มันเพราะอะไร เพราะว่าการจัดอนุภาค อนุภาคที่อยู่ในของเหลว และแก๊ส มันจัดตัวต่างจากของแข็ง อันนี้ก็ลืมพูดไป บางที่มันเร่งจนกระทั่งลืม องค์ความรู้ บางอย่าง เราก้ไม่ได้พูด ซึ่งบางที่เราก้เสียดายเหมือนกันมันน่าจะได้อธิบาย

I start by briefing the chemistry concepts in the Standards to teachers in order to provide an image to them about the framework, such as what students have to learn at primary grades. Then, I have teachers do activities and then I explain content knowledge and knowledge of laboratory techniques to them. When teachers are doing activities, I walk around and remind them of the techniques. I know that there is much content knowledge that I want to give to them, but I forget. For example, why solid, liquid, and gas have different properties in terms of mass, volume, and shape. Unfortunately everything is in a hurry so I forget to tell them. (Somsri, Interview #2)

Hence, Somsri displayed her knowledge of PD strategies in that she was able to describe and demonstrate the 5E to teachers during the PD. She also helped teachers to relate this strategy to their use in their classrooms.

Somsri exhibited her knowledge of representation of specific topics by providing direct explanations to the teachers. Somsri claimed that during the PD:

ถ้าอาจารย์ทำการทดลองช้า เราก้ไม่มีโอกาสจะบอกสิ่งที่อยากบอก เพราะฉะนั้นอาจารย์ รีบๆ ทำกิจกรรม เราจะได้บอก concept อาจารย์จะได้ได้ concept ไปด้วย
If you do not hurry, I won't have opportunity to explain to you. So, if you want to have the concept, you need to hurry. (Somsri, During PD Implementation)

Her PD implementation revealed that Somsri only demonstrated one way of representation in order to facilitate teachers' learning. In addition, the excerpt above also reveals that Somsri believed that without her explanation, the PD activities alone could not be used to help teachers comprehend important information about the specific concepts.

Knowledge of PD Curriculum. Somsri exhibited her knowledge of the PD curriculum in that she described to teachers the framework of the IPST curriculum and how it served the Standards. In addition, she was able to explain what activities were necessary to put into the PD curriculum and why.

อย่างกิจกรรมที่เราจัดมาเราก็คิดว่าจัดมาครอบคลุม ตั้งแต่ ป1 - ป6 แล้ว ถ้าเพื่อนน้อยกว่านี้ เราก็คิดว่ามันจะน้อยไป มากกว่านี้ก็ไม่ไหว ถ้าแค่นี้ เราก็คิดว่าถ้าเร่งหน่อย ถ้าเร่งแบบรีบ ๆ มันคงจะทัน เราก็เลยเอาแค่นี้

The activities that are in the PD curriculum cover the content for 1st-6th grade. If we prepare less than this, I feel it is not enough. But, we cannot provide more activities or content than what we prepare right now because we don't have enough time to talk and implement in the PD (Somsri, Interview #1)

Somsri knew that there were not answers in the activity worksheets, which were in the activity handbook. Thus, she rushed teachers to finish activities, so she could have more time to her to provide answers and information for answering the questions on the worksheets.

Knowledge of assessment of scientific literacy. Somsri was the only professional developer whose central goal was to develop teachers' content knowledge in the chemistry topics that they had to teach in their classroom. However, she did not explicitly display her knowledge about what aspects of teachers' learning were important to assess within the chemistry concepts in the PD. The information about teachers' learning of the concept she taught was only from her senses--by discussion and interaction with teachers during her session.

จากปัญหาที่บอกคือเนื้อหามันเยอะ เวลามันไม่ทันถ้าจะทำอย่างนั้นมันต้องเพิ่มเวลาเวลาอบรมต้องมากกว่านั้น เขาก็มีชั่วโมงวัดผล ซึ่งวัดผลทุกๆไปเป็นหลักการวัดผลทุกๆไปไม่ได้ วัดผลในเนื้อหาที่เราอบรม ไม่ได้วัด ไม่มีโอกาสได้วัดเลยเราตัดสินไม่ได้ เราก็บอกไม่ได้ เพียงเราสังเกตอาการความสนใจของเขาว่าเขาอยากรู้อยากเห็นเขาก็ตั้งใจที่เราคิดว่าเขาจะต้องได้ความรู้ส่วนนั้น แต่เราไม่มีโอกาสไปวัดหรือประเมินผลเขาได้เลย

The problem is there are too many contents. We don't have time if we do assessment in the PD. If we want to do it, we have to extend the days. Actually, we have a session for evaluation, but it is not for assessing

teachers. We just give general assessment knowledge to teachers. (Somsri, Interview #1)

มันไม่มีโอกาสได้คุยไม่มีโอกาสพอหมดเวลาก็แยกกันไปเลยไม่มีเวลาคุย เพียงแต่ว่าเราจะรู้ ว่ากลุ่มไหน รุ่นไหนมาสนใจมาก สนใจน้อย ถ้าเขาสนใจมากเราก็คิดว่าเขาต้องได้ความรู้ มากถ้ารุ่นไหนไม่ค่อยสนใจทำLabก็นั่งดูเฉยๆให้เพื่อนทำตัวก็นั่งดูเราก็คิดว่านั่นนะไม่ประสบความสำเร็จหรอก เราประเมินด้วยความรู้สึกของเรา แต่ถ้าเราเห็นเขากระตือรือร้นทำช่วยกัน ทำ ทำตรงไหนไม่ถูกเราก็แนะนำเราก็คิดว่ามันน่าจะได้ผลดีกว่ากลุ่มที่นั่นนะ แต่การไป ติดตามผลเราไม่มีโอกาสรู้เลยว่าได้ผลดีหรือไม่ดีแค่ไหน เรารู้แต่ว่าพื้นฐานความรู้ของครู อย่างเอกชน พวก สช. เราารู้สึกว่าเค้าจะมีพื้นฐานค่อนข้างดีกว่ากลุ่มกรมการปกครอง หรือ พวกครูเทศบาล

We don't have time to talk to teachers after the session or PD. I can only tell the success from teachers' performance in doing the activity. If they do an activity actively, so it might succeed in terms of they may understand it and use it with students. But, we don't have a follow-up plan to observe that whether or not they really understand and use it. But, I believe that this group of teachers has more knowledge than the public school teachers, so it might work. (Somsri, Interview #2)

According to knowledge of methods of assessment, Somsri did not display this type of knowledge. She mentioned that she did not have enough time to do the assessment of teachers' understanding of science concepts. She indicated that if she included assessment, then she had to reduce the number of activities for teachers, which she did not want to do.

รู้สึกทุกสาระเลยไม่ได้วัด คิดว่าเวลาไม่พอ เพราะว่าจากที่ประชุมสาขาเราก็พูดตลอด ว่า เวลาไม่พอ เวลานั้นน้อยไป เพราะฉะนั้น เรื่องวัดผลนี่คงไม่มีทางที่จะทำได้ ในช่วงโมงนอกจาก จะเพิ่มเวลา เพราะเรื่องเพิ่มเวลาเราพูดกันตลอด แต่ที่นี้ทางสาขา เขาบอกว่างบไม่พอที่จะ จัดหนึ่ง สองถ้าเพิ่มเวลาครูเขาจะทิ้งโรงเรียนมานาน ทำให้เขาเสียการสอน ปัญหามันหลาย ๆ อย่าง แต่ถ้าให้หนักก็คือเราลด lab ลดการทดลองลง เราทำได้ แต่ที่นี้เราอยากให้เขาได้ เยอะ ๆ

None of the PD sessions do the assessment. It is not possible under the time restriction. If the department really wants me to do assessment, that means I have to reduce the labs, which I don't want to. I want teachers to have many labs (Somsri, Interview #1).

In summary, Somsri held moderate understanding about the IPST curriculum. She could explain the framework of content knowledge that was in the IPST curriculum.

However, similar to other professional developers, Somsri held limited PCK for PD on understanding teachers' learning, PD strategies, and assessment methods. Somsri did not

know teachers' prior knowledge, learning approaches, or misconceptions. Although Somsri mentioned about the 5E model of instruction, she did not display how much she knew about this teaching strategy, using only engagement activities in the PD. Somsri believed that the 5E strategy provided opportunities for teachers to participate in hands-on activities and helped teachers to practice and understand the science process and develop laboratory skills, but she did not use the entire learning cycle. In regards to her knowledge on assessment, Somsri did not explicitly display her knowledge about what aspects of teachers' learning were important to assess within the chemistry concepts in the PD. Somsri used discussion and interaction with teachers during her session as ways to observe teachers' understanding.

Sommit's Implementations, Orientations, and PCK to Professional Development

PD Implementation

During the PD implementation, Sommit started his session by introducing chemistry topics that were in the IPST Curriculum. He indicated to the teachers that he hoped they already knew about the 5E model of instruction from the previous PD sessions. Thus, he did not explain this teaching strategy again. The activities that Sommit introduced to the teachers in his session were exactly the same as the activities that Somsri provided to the teachers in another group. However, his PD strategy was completely different from Somsri's. Sommit believed that the PD teachers already had good content knowledge in primary science and those activities in the IPST Curriculum were easy for the teachers. Thus, he let the teachers decide which activities they wanted to do, based on their interest. Sommit indicated that the teachers did not have to do the activities that they already knew.

อันไหนที่ง่าย ง่ายคือครูเขาเคยทำมาแล้วมีภาพในหนังสือเราเล่าเรื่องแล้วครูเขาเข้าใจก็จะเล่าให้ครูเขาฟังเฉยๆ โดยที่ไม่ต้องลงมือทำ แต่ถ้ามอดดูแล้วว่ากิจกรรมนี้ยังงี้ๆครูต้องทดลองเพื่อให้เห็นจริงๆเพราะว่าเราเล่าแล้วครูนึกภาพไม่ออกตรงนี้ต้องลงมือทำ เราจะเล่าว่าใส่อันนี้ผสมอันนี้ลงไปแล้วเกิดสีนี้เกิดแก๊ซนี้ยังงี้ๆครูก็จินตนาการไม่ออก เพราะฉะนั้นครูต้องพยายามให้เด็กได้ปฏิบัติกิจกรรมที่มันเป็นกิจกรรมแต่ส่วนใหญ่แล้วครูต้องทำกิจกรรมแทบทุกกิจกรรมเพื่อสอนเด็ก ยกเว้นแต่ว่ามันง่ายเกินไปเราจะข้าม แต่บางอย่างถึงแม้ว่ามันง่ายแต่บางคนเขาก็ไม่เคยทำ เขาก็จะทำเพราะอุปกรณ์เราเตรียมไว้ให้หมด อุปกรณ์เราเตรียมให้บนโต๊ะหมดแต่เราจะให้เขาทำกิจกรรมนี้ๆหรือกิจกรรมอื่นที่แต่ละกลุ่มสนใจทำที่มีในคู่มือเราครูก็สามารถที่จะทำได้

For the basic activity, which means teachers used to doing it before or we have pictures of that activity in the resource book, I will skip or just give details of that activity. However, if I notice that the teachers won't understand it only by telling them, then I will have them do the activity. Indeed, the teachers need to do and understand every activity because they have to allow the students to do every activity as well. But, if the activity is too easy, I have materials for them so they can practice it if they want. (Sommit, Interview #1)

Before the teachers started doing activities, he explained which activities he recommended that they do and what alternative activities that each group could decide to do. Then, he let each group of teachers explore the activities on their own. While the teachers were doing the activities, Sommit visited each group to observe them performing the activities. As opposed to Somsri, Sommit did not have every group of teachers do each activity step-by-step by following the suggested instructions. Rather, he encouraged the teachers to design their own investigations.

ถ้าเราปล่อยให้ครูเขาคิด ถ้าครูเขาเกิดปัญหา เด็กก็จะเกิดปัญหา กระตุ้นให้การช่างคิดช่างสังเกตได้หลุดออกมา ถ้าเค้าไปถาม เราก็ไม่ตอบให้เค้าได้คิดเอง เราก็ได้เห็นพฤติกรรม ของครูทำอะไรแปลก ๆ

If we have the teachers thinking on their own, they will be able to pose questions. We are trying to encourage them to think, and be observant. When they ask some questions, I try not to answer those questions. I want them to think on their own and, at the same time, I can see what they are going to do. Hopefully, they will do it like this with their students, too. (Sommit, Interview #1)

However, his endeavor did not seem to succeed because the teachers still followed the activity instructions when they did the activities. During his visits with each group, Sommit asked several questions to the teachers in order to initiate their thinking about the

activities. However, his questions were closed and subject-centered. It appeared that Sommit did not pay attention to the teachers' responses to his questions. He did not revisit the groups to observe how his questions influenced the teachers to action. Sommit rarely responded to teachers' questions, but informed teachers that they needed to check those out when they left the PD. Unlike Somsri, Sommit did not seriously explain science concepts to the teachers, because he indicated that the knowledge of those concepts was already in the PD manual. Thus, the teachers should go back and read it.

ครูก็ไม่รู้ว่าเขาทำแล้วอธิบายก็ไม่ได้ ต้องไปค้นต้องไปถามผู้รู้อีกทีหนึ่ง เพราะว่าบางคำตอบเราไม่สามารถตอบเด็กได้ในชั่วโมงนั้น หรือบางที่เราอาจจะไม่รู้ก็ได้บางอย่างอาจเป็นเรื่องใหม่สำหรับครู เราก็ต้องลองแล้วไปค้นซึ่งมันมีคำตอบอยู่แล้ว
I know the teachers were not able to explain about the activities. They need to find those explanations by themselves. It is like in the classroom. Sometimes when the students have questions, we can't answer all of the questions. Sometimes, it is new to the teacher, too. So, they need to try out the activity and find the explanation later, which, of course, they can find it somewhere. (Sommit, Interview #2)

Similar to other professional developers in the PD, Sommit took a major role as a lecturer. However, his lecture consisted mostly about his experiences with previous PD projects with teachers or informing the teachers of general knowledge or things that they should be aware in doing each activity, rather than focusing on providing scientific knowledge. Unlike Somsri, Sommit only provided brief conclusions after the teachers finished the activities. He did not explain specific science knowledge, but only reviewed general knowledge or techniques that the teachers needed to know. During the PD implementation, Sommit mentioned that sometimes the students already knew the concepts that they were going to study. Thus, the teachers need to check the students' understanding of a topic before the instruction. He instructed them that if the students were familiar with the concept, the teachers could either abandon that concept or expand the concept in more depth. It was interesting that when Sommit was teaching his session,

he always mentioned to the participants about TV programs that used scientific knowledge to solve particular problems. He suggested that teachers videotape those programs to use in their science classrooms. The teachers could use those tapes either before the instruction to engage students in the science lesson or after the instruction to check students' understanding of the concept. Sommit indicated in the interview that the teachers should watch these programs because they can answer the students' questions when asked.

ก่อนที่จะทำกิจกรรมแต่ละกิจกรรมเราน่าจะมีกิจกรรมที่เป็นกิจกรรมสร้างความสนใจมันเป็นแบบโชว์ๆ ตั้งคำถามแบบท้าทายให้คิดที่จะตอบคำถามนี้ได้ต้องอาศัยเรื่องที่เรียนนี้มาตอบ เหมือนกับเกม Mega Clever สร้างปัญหาแบบนั้นหลายๆปัญหา ยังตอบไม่ได้คิดไว้ก่อน แล้วทำกิจกรรมถ้ามีประเด็นอย่างนี้ครูเขาน่าจะสนใจ ถ้าเป็นครูอาจจะตอบได้แต่ถ้าเป็นเด็กอาจจะตอบไม่ได้ต้องเรียนก่อนจึงจะตอบได้อาจจะมีตัวอย่างให้ดูเป็นตักตาสัก 2-3 ตัวอย่าง Before doing the activity, I will provide a show for them and ask them questions in order to make them think. Like a TV program called Mega Clever, it uses problem-solving techniques by introducing many scenarios or circumstances for people to find ways to solve problems. I think this kind of activity might be interesting to teachers, which they might use with their students as well. I will provide 2-3 examples for them. (Sommit, Interview #1)

However, when Sommit implemented the PD, it appeared that although he showed an activity that he called “science show activity,” he did not focus the teachers as he stated during the interview. For example, the science show activity that Sommit demonstrated to teachers was called a magic cup. Sommit started this show by pouring water into one of three plastic cups. Then, he rotated those cups quickly and asked teachers what cup had water in it. He did the same pattern for three times and then turned each cup down. Teachers were very surprised when they found that water had disappeared. Sommit asked teachers where the water was. Teachers said that there might be something in the cup that could absorb water. Sommit responded to this by telling teachers what material he put in the cup. Sommit also named other materials that could absorb water. However, Sommit

seemed to miss his goal of stressing to teachers see the purpose and importance of the engagement activity to students' learning. In other words, instead of helping teachers connect this experience to classroom teaching, Sommit only told teachers that they could use this activity with their students and then he walked teachers through other activities in the manual.

Orientation

Figure 14 represents my analysis of Sommit's orientation to PD. I found that, during the interviews and PD implementation, Sommit's orientation to PD consisted of two central goals and three peripheral goals. Sommit's central goals were quite similar to Somsri in that they pertain to the following: 1) to introduce scientific activities in the IPST Curriculum that were aligned with the reformed National Science Standards, and 2) to develop PD participants' laboratory skills necessary to make the activities work.

เป้าหมายจริง ๆ แล้วเราต้องการให้ครูที่มาเข้ารับการอบรมได้เข้าใจกระบวนการเรียนการสอนวิทยาศาสตร์และได้รู้เนื้อหาของวิทยาศาสตร์ด้วย คือต้องรู้ทั้งเทคนิคการสอนและรู้เนื้อหาคือ Concept หลัก ๆ อีกอันหนึ่งก็เรื่องการวัดผลประเมินผลรู้ถึงการใช้สื่อ ด้านการสอนลักษณะของรูปแบบการสอนที่เราจะให้ส่วนที่เป็นตัวอย่างการสอนให้ในคู่มือเรามีวิธีการเขียนแผนการสอนที่เป็นแบบ 5E หรือเป็น Inquiry เป็นตัวอย่างให้ครูเขาเวลาสอนจริงเราก็แนะนำเป็นส่วนๆ ไป

My goals are to help teachers to understand the teaching and learning process, content knowledge, concepts, teaching techniques, assessment strategies. We provide examples of the 5E model of instruction or inquiry as well. (Sommit, Interview #1)

Sommit believed that his job is to expose teachers to the information and make them aware of that information. His job was also to help teacher improve their laboratory skills and understand the purpose and importance of the activities through performing hands-on activities.

เราอยากให้เป็นเทคนิคปฏิบัติมากกว่า เพราะเข้าใจว่า ครูกลุ่มนี้ถ้าสอนถ้าเปิดตำราสอน เขาก็สอนไปตามตำราโดยที่ไม่เข้าใจหรือความซาบซึ้งในการทำกิจกรรม เขาอาจจะไม่รู้ว่าทำไปทำไม มีประโยชน์อะไร ทำแบบนั้นแล้วเด็กเกิดความคิดอะไรบ้างที่เรานั่นทำกิจกรรม เพื่อให้ครูเขาเห็นว่าการทำงานกิจกรรมตัวครูเอง ก็ยังตื่นเต้น ยังมีความรู้สึกว่ามันน่าสนใจนะ มันมีคำถามเกิดขึ้นมากมายที่ไม่น่าเกิดอย่าง

I want to improve their techniques because most of teachers follow the textbook or activity book without appreciation of the activities. They don't know the purpose and learning goals of the activities. What students will achieve when they do those activities. I want them to realize how excited they are when they are engaged in the activities. (Sommit, Interview #2)

Sommit demonstrated that improving content knowledge in chemistry was not his primary goal for this PD. He indicated that:

ที่ไม่ให้ความรู้ส่วนใหญ่ในเอกสารของเรามีเอกสารที่ อ.นัทสรวง ทำไว้มันมีเนื้อหาอยู่แล้ว เพราะฉะนั้นคิดว่าครูเขาน่าจะไปอ่านเองได้ ที่เราพยายามทำคือให้ครูเค้าเกิดปัญหา I don't give explanation about knowledge to teachers because it already is in the manual. Teachers can read that explanation from there. What I want them to have is seeing the problems. (Sommit, Interview #2)

Sommit indicated that Somsri and he already provided all necessary knowledge for teachers in the PD handbook. Hence, they could read this knowledge anytime after PD.

Sommit gave an example of one activity in the PD that introduced the concept that a gas can change its shape based on its container. According to this activity, teachers had to tie one end of a plastic tube to a balloon containing air and tie another end to a rubber glove. Teachers had to observe what happened after they released air in balloon through the tube.

ยกตัวอย่างกิจกรรมลูกโป่ง มีบางกลุ่มก็พยายามบีบ ๆ จนจากลูกโป่งเข้าไปในถุงมืออย่างจนถุงมืออย่างพอง ปัญหามันก็จะเกิด เวลาบีบบกลับมาทำไมมันบีบบกลับมาไม่ได้ที่จริงมันมีหลักการทางฟิสิกส์อธิบายเรื่องนี้อยู่ แต่ว่าเราไม่สอนเรื่องนั้น แสดงว่าเรื่องนี้เป็นสิ่งที่ละเอียด ถ้าเขาไปทำกับเด็ก ถ้าเป็นเด็กเก่ง ๆ ที่ชอบเล่นเด็กจะบีบแล้วก็เกิดคำถามตามมาที่นี้เด็กก็อยากจู้ ครูก็อยากจู้ ก็ต้องไปค้นหาหรือถามผู้รู้ ถ้าเราไปสอนครูเขาอาจจะไม่เข้าใจว่าบีบไปแล้วมันเคลื่อนที่จากที่มันมี pressure มากไปที่ pressure น้อยจากมากไปหาน้อย แต่ทำไมพอไปอยู่อีกฝั่งหนึ่งแล้ว pressure มันมากกว่า ปริมาณมวลของอากาศน้อยกว่าทำไมมันไม่ยอมเข้ามาในลูกโป่ง แล้วคราวนี้มันมีเรื่องสภาพยืดหยุ่นของลูกโป่งเข้ามาเกี่ยวข้อง ซึ่งตรงนี้เราไม่ได้อธิบาย ครูเขาเกิดปัญหาอีกหลายกลุ่ม ที่มีปัญหาเหล่านี้ ส่วนใหญ่ก็ไม่เคยเจอปัญหานี้บางครั้งก็มาเจอ ถ้าเราปล่อยให้ครูเขาคิด ถ้าครูเขาเกิดปัญหา เด็กก็จะเกิดปัญหา กระตุ้นให้มีมโนกรรมที่อยู่ในเด็กให้ขงคิด ขงสังเกตุได้หลุดออกมาถ้าเราไปถามเด็ก ๆ เขาก็ไม่ตอบ เราก็เห็นพฤติกรรม ของครูทำอะไรแปลก ๆ ครูก็ไม่รู้นะเขาทำแล้วอธิบายก็ไม่ได้ ต้องไปค้นต้องไปถามผู้รู้อีกทีหนึ่ง เพราะว่าบางคำตอบเราไม่สามารถตอบเด็กได้ในชั่วโมงนั้น หรือบางที่เราอาจจะไม่รู้ก็ได้บางอย่างอาจเป็นเรื่องใหม่สำหรับครู เราก็ต้องลองแล้วไปค้นซึ่งมันมีคำตอบอยู่แล้ว

For example in the balloon activity, some groups tried to squeeze the balloon to move air inside it into the rubber glove. But, they found that they couldn't do it. Teachers didn't know why they couldn't. So, they have curiosity and want to know the answer. But, they have to find the

answers on their own. If I teach them, they won't understand it because there are many concepts to explain about this phenomenon. Teachers won't understand about pressure or elasticity of the balloon. I encourage them to do this activity because I want teachers to have curiosity and think about it. Then, they will do the same thing with their students. However, they have to find the answers on their own by asking expert or reading from the textbook. I cannot answer all the questions. (Sommit, Interview #2)

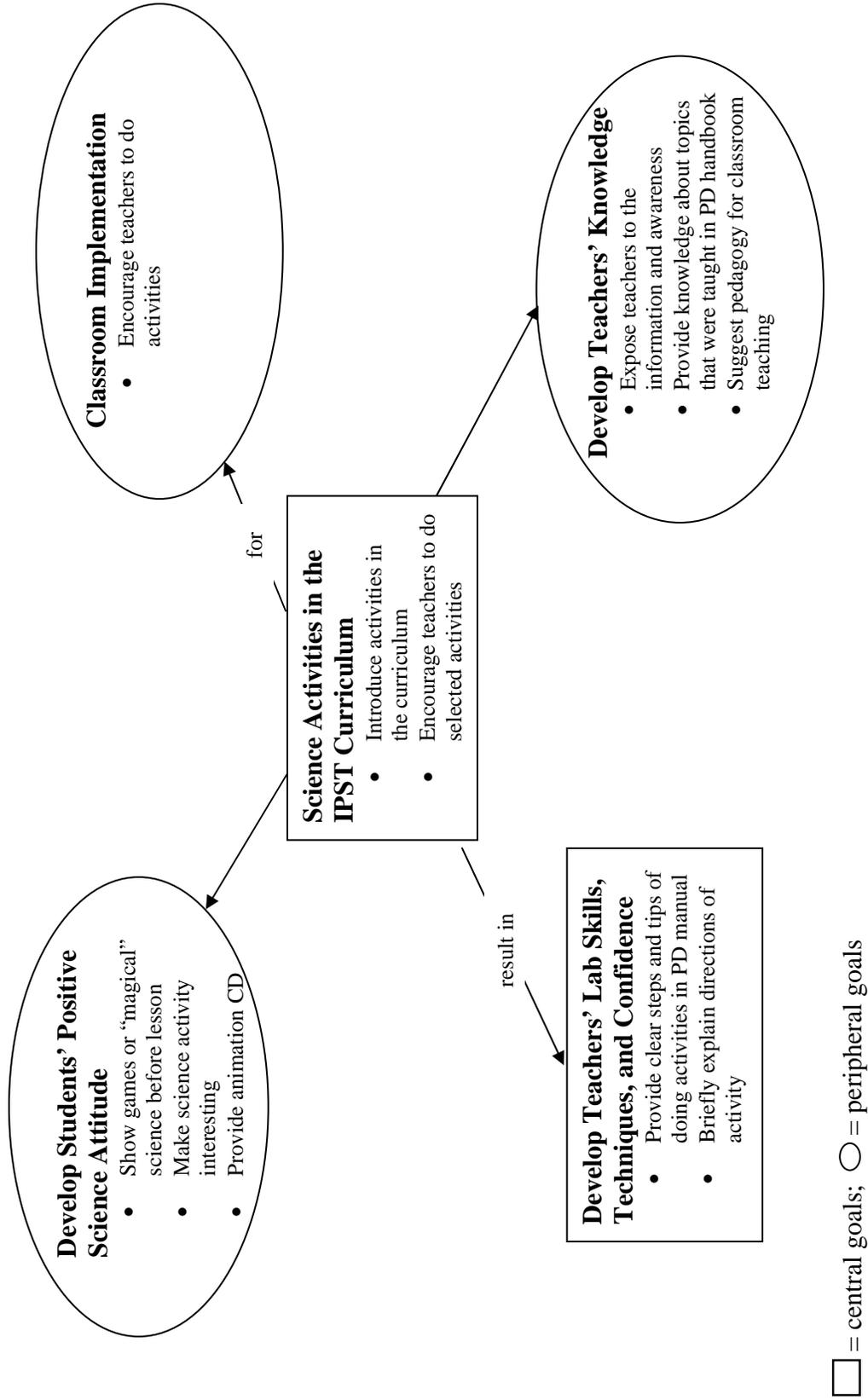
The excerpt above reveals that Sommit saw himself as having a role in initiating teachers' curiosity, while the teachers had to take responsibility in finding the correct answers themselves. He wanted the teachers to get excited with the activities and focused less on teachers' understanding of the scientific concepts beyond the activity.

ไข้อยากจะให้เค้าสงสัย เพียงแต่ว่าขั้นตอนในการจะหาข้อมูล เราแนะนำไปบ้าง เช่นเข้าไปใน internet หรือถามผู้รู้หรือถามมาทาง สสวท.ก็ได้
Yes, I want them to have curiosity. I may provide some information to them, but if they really want the answer they might find it from the internet, expert, or IPST staff (Sommit, Interview #2).

However, during the explanation phase, Sommit provided general knowledge, such as the connection of the concept that was taught to everyday experience rather than helping teachers develop understanding about that particular concept. For example, after teachers finished activities on chemical changes, Sommit provided knowledge about advantages and disadvantages of chemical changes rather than conceptual understanding on this topic.

ที่สำคัญเราอยากให้เค้ารู้ว่าปฏิกิริยาเคมีมันมีทั้งข้อดีและข้อเสียเวลาเราสอนเราจะยกตัวอย่างปฏิกิริยาเคมีให้ทั้งข้อดีและข้อเสียโยงไปถึงชีวิตประจำวันให้เขาเห็นผลกระทบ
I want them to recognize pros and cons of chemical reactions. So I will provide information about the pros and cons and also link to their real-life experience. (Sommit, Interview #1)

Figure 14. Sommit's Goals for PD



In addition to reviewing activities in the IPST Curriculum, Sommit also compared the activities in previous and current IPST Curricula in terms of their advantages and convenience.

เปรียบเทียบกับสิ่งที่สอนดูแล้วพิจารณาว่าสองอัน อันใหม่ที่เราเสนอให้กับวิธีเดิมที่เค้าเคยสอนมาว่าสองอันนี้ อันไหนมันดีกว่ากันแล้วให้เขาพิจารณา แล้วเอาไปเลือกใช้ นั่นคือเราเสนอทางเลือกให้เขาซึ่งอาจจะบอกแบบเดิมดี เขาเลือกแบบเดิมก็ไม่เป็นไร แต่ถ้าเขาทำแบบเราเขาก็จะมีข้อดีคือประหยัดเวลาประหยัดสารเคมี

I compare activities in previous and new curriculum to teachers, how the new one is better than the previous one. However, they have to make their own decision what activity they are going to use. It doesn't matter if they use the old one, but it is better if they use the new one because it saves time and chemicals (Sommit, Interview #2).

คาดหวังว่ากลับไปแล้ว เขาคงจะทบทวนนะ หลักสูตรที่เราเสนอให้เขาเป็นหลักสูตรตาม พบ. ใหม่ที่โรงเรียนหรือครูทุกคนจะต้องสอนกิจกรรมลักษณะนี้ เพื่อให้ตรงตามมาตรฐาน ลักษณะของกิจกรรมอาจจะแตกต่างก็แล้วแต่ เพราะว่าตัวอย่างที่เราเสนอให้มันเป็นเพียงตัวอย่างเพื่อให้ได้ concept ตามมาตรฐานก็เท่านั้นเอง แต่ไม่ได้หมายความว่าทุกคนต้องทำกิจกรรมตามเราแบบนี้ อย่างเรื่องการนำความร้อน บางคนก็ใช้วิธีเดิมก็ไม่เป็นไร แต่เราเสนอวิธีง่าย ๆ

I anticipate that teachers will recall what they learned from us. Our curriculum is aligned with the Standards that they have to teach at school. We try to use activities that introduce the concepts that are required in the Standards. We give them a choice, but we cannot do anything if they don't use it. (Sommit, Interview #2)

Sommit provided current IPST activities to teachers and made comparisons between the previous and the current curricula because he wanted teachers to have more choices in selecting activities for students. However, the purposes in giving activities were related to teachers' convenience in preparing materials, time, and other factors rather than the relation to student learning.

In order to help teachers to develop laboratory skills, Sommit visited each group of teachers to observe their skills during the activity. Sommit warned the teachers when they did not demonstrate good scientific laboratory skills or when the teachers used too many chemicals in an experiment. He also suggested the teachers use alternative ways in doing the activity.

Sommit's peripheral goals were to (1) develop knowledge and techniques necessary for teaching to teachers, (2) promote classroom implementation of PD activities, and (3) promote students' positive attitude toward science. Sommit indicated that he did not have time to provide content knowledge to teachers during the PD, but the knowledge that was necessary for teaching was already in the PD handbook. Thus, teachers would increase their knowledge if they read the PD handbook after they left the PD.

To meet his goal on promoting students' positive attitude toward science, Sommit provided the participants with a CD that had animation games. He indicated to the teachers that they should encourage students to link their knowledge in the science classroom to their everyday experiences. He believed that when the students saw the connection of science knowledge to their lives, students would have a more positive attitude toward science.

Table 10 showed the arrangement and reflection on the cards sort scenarios that Sommit selected as most representative of his PD teaching. Sommit indicated that scenarios 8 and 9 closely represented his PD strategies for this PD. Sommit indicated that he used these strategies in the PD. Sommit's reflections on these two scenarios were also supported with interview data.

บางกิจกรรมให้เขาทำให้เขาได้ลงมือปฏิบัติแล้วให้เขาได้ข้อสรุปจากการปฏิบัติจริง ๆ เราจะ
ไม่สอนว่าอันนี้ Concept ว่าไง จะไม่เป็นแบบบรรยาย ให้เขาทำให้เขารู้ตรงนั้นแล้วค่อยทำ
กิจกรรม เสร็จแล้วค่อยสรุปว่าตรงนี้มี Concept อะไร ข้อควรระวังมีอะไรบ้างหรือว่าถ้าไปทำ
การเรียนการสอนท่ามาถึงขั้นนี้เกิดผลอย่างนี้แล้วครูน่าจะทำอย่างไร ครูน่าจะถามอะไรกับ
เด็กเพื่อกระตุ้นให้เด็กเกิดความรู้ขึ้นมา

I won't explain or give knowledge about the concept to them right way. I
will have teachers to do the activity and then I will tell them the concepts,
awareness of safety, questions that they should ask students to encourage
their interest. (Sommit, Interview #1)

เราก็ต้องให้เขารู้มาตรฐานวิทยาศาสตร์ของประถมมีอะไรบ้างแล้วเราก็ให้ความรู้หรือให้ตัวอย่างกิจกรรมในบ้านที่กิจกรรม

I will provide a framework of chemistry concepts shown in the Standards, such as what chemistry knowledge primary students need to learn. I will provide an example activity and its worksheet to teachers. (Sommit, Interview #2)

Although Sommit placed scenario 9 in a group that represented his teaching strategies, he determined that he did not want to model science teaching. Sommit believed that the teachers did not need to follow his way of teaching. Instead, the teachers had their own teaching styles. They only needed to adjust what they learned in the PD to their own teaching style.

เราไม่ได้อยากให้เค้ามาตามแบบเรา เค้าไม่ต้องมาสอนเหมือนเรา ครูเค้ามีเทคนิค มีวิธีสอนของตัวเอง เพียงแต่เราให้ ideas เค้า ให้เค้าได้ทำกิจกรรม ได้ฝึกทักษะ เดี่ยวเค้ากลับไปเค้าก็เอาไปสอนตามแนวทางของตัวเอง

I don't want them to copy my teaching, it isn't necessary. Teachers have their own way of teaching. So, I will only help them to develop ideas, activities, skills, teaching skills and then they will modify to their own teaching. (Sommit, Interview #1)

However, Sommit put scenario 9 in the “like me” group because the team’s purpose of this PD was to help the teachers understand the activities in the IPST Curriculum. He mentioned that if it was possible, he would like to use a problem-based strategy or other strategies in the next PD.

Table 10

Sommit's Arrangement and Interpretation of the Card-Sort Scenarios

Items	Scenarios	Sommit's Interpretations
8	You, as a professional developer, design a PD lesson on dissolution by encouraging teachers to do activities that their students would do. At the end of session, you assign teachers to discuss within their group, then as a whole about what they learn about dissolution and about teaching this unit. (reflective)	"This is what I do in the PD. Teachers need to do the same activities that they have to teach students. Then, I encourage them to discuss about their results. I may have them compare their results to other groups. Then, I provide more information about the activity, such as its application." (activity-driven)
9	You, as a professional developer, begin a unit on sound by introducing curriculum, explaining materials, allowing teachers doing activities, and you explaining the concepts at the end of activities. (didactic)	"Introducing curriculum to teachers to help them have a big picture about the curriculum, such as what's in there. For this PD, I do everything similar to this scenario because I want teachers to know curriculum, be able to do activities, and use with students. However, I may change strategy in the next PD." (didactic)
15	As a professional developer, you begin a unit of heat conduction by engaging in activities that you hope the teachers will use with their students. You demonstrate teachers to use whiteboarding and cooperative learning in teaching those activities. (pedagogy-driven)	"I introduced the heat conduction kit, then encouraged them to guess which material best conducts heat. Then, teachers explored on that kit and did the activity and compared their results to other groups. I encouraged them to find reasons in case their results deviated from other groups. We used whiteboard to present the findings because I saw this example when I visited the US and then I brought this idea to teachers." (activity-driven)
14	You, as a professional developer, set up a variety of materials at a back of room for teachers to investigate about sound has different properties such as pitch, volume, and timbre. (inquiry)	"This scenario represents what I like to do. I want teachers to explore the activities based on their interest. I provide the overview of each activity at the beginning and tell teachers that I prepared materials for them at the back of room. So, they can decide what activities they want to do. They don't have to do the activity that they already know." (activity-driven)
12	Teachers have just completed a simple circuit with multiple bulbs. For the next unit on electricity, you ask the teachers to make the bulbs light using a combination of wire, bulbs, and switch. (guided inquiry)	"We can have teachers do the activity before, like trial and error things. Then, we explain to them later about function of each material." (activity-driven)

Sommit also mentioned that he asked teachers questions when they were doing activities in order to help teachers develop their creativity by guiding them to solve some other problems that were not included in the activity manual.

มันไม่มีในกิจกรรม พอเราโยนคำถามให้ครูเขาเกิดความคิดสร้างสรรค์หาวิธีที่จะเอาแก๊สในลูกโป่งมาทดสอบกับน้ำปูนใส มันก็ได้หลายแบบตรงนี้ก็เป็นการฝึกให้เขารู้จักสร้างกิจกรรมขึ้นเอง ไม่ต้องทำตาม Direction ของเราที่เขาไม่รู้ คือเขาอาจจะมีความคิดทำกิจกรรมตรงนั้น เราเพียงแต่ตั้งคำถามและให้เขาหาวิธีการเท่านั้นเอง จะทำประจำในระหว่างที่สอน It doesn't have it in the activity worksheet, but I want them to have creativity so I throw questions for them to solve problems. They don't have to follow direction. I will usually do this technique when I deliver PD. (Sommit, Interview #1)

He expected teachers to develop curiosity and then find out the information later. In addition to developing teachers' creativity, he also wanted teachers to recognize how curiosity led them to want to learn science. He anticipated that teachers would bring this feeling back to school and use it with students in order to develop students' thinking skills. However, his endeavor about increasing teachers' creativity did not show any relation to the development of knowledge. Sommit stated that the time restriction of the PD session did not allow him to provide explanations or answers to his questions.

In addition to the time restriction, Sommit explained that he did not provide content knowledge on heat conduction to teachers because he believed that teachers already understood this concept. Thus, he decided to provide its application instead of the body of content knowledge.

การนำความร้อน เรื่องช้อนโยงมาถึงว่าของใช้ในบ้านทำไมมันมีส่วนที่เป็นฉนวน ส่วนนั้นก็ไม่อธิบาย แต่คิดว่ามันมีในเนื้อหาอยู่แล้วมีในเอกสารอยู่แล้ว ถึงแม้เราไม่ได้อธิบาย คิดเองนะ โดย sense ของครูหรือของผู้ใหญ่มันก็ต้องรู้ว่าอันนี้มีประโยชน์อะไร คิดว่ามันมีในเนื้อหาอยู่แล้วก็ไม่ได้อธิบาย ถ้าเราไปอธิบายอีกมันก็จะทำให้เสียเวลา concept นั้นครูก็รู้แล้ว ก็เลยข้ามไปคิดว่าครูน่าจะรู้ น่าจะพออธิบายได้

To teach the heat conduction topic, I will help them make connection with what products have heat insulator and conductor properties that we commonly use in a household. But, I don't explain about the content. I think they already know it because they are teachers, or adults might know it also. So, I won't spend time to repeat this knowledge again, but I skip this explanation part because I think teachers should know. In addition, we already explain it in the activity manual. (Sommit, Card Sort Activity)

As indicated in Table 8, the strategies in scenario 14 were ones that Sommit would like to do. After he introduced the IPST Curriculum and its framework, the

teachers were provided with materials for each activity. He wanted the teachers to predict the results before doing the activities. His reflection on this scenario confirmed his belief about the role of the professional developer when he explained that he would observe the teachers doing their activities and post critical questions to the teachers when necessary. If some groups of teachers did not have the same results as other groups, he would not answer their questions. Instead, he would encourage them to try the activity again.

ฉันนี่ที่อยากทำ คือใครสนใจกิจกรรมไหนก็ทำ เราอธิบายภาพรวมก่อนจากนั้นเราก็บอกครูว่าอุปกรณ์ตั้งไว้ด้านหลังห้อง ใครสนใจจะทดลองกิจกรรมไหนก็ลองทำดู เพราะครูบางคนเค้ารู้แล้วว่าอากาศมีมวลเค้าก็ไม่ต้องทำกิจกรรมซึ่งมวลอากาศ แล้วเราก็ไม่ต้องเตรียมเครื่องซึ่งให้ทุกกลุ่มด้วย กลุ่มไหนไม่รู้ก็ไปทำตรงอุปกรณ์ที่เรา set ไว้ให้ อย่างเรื่องการนำความร้อนเราก็แนะนำการใช้อุปกรณ์ก่อนจากนั้นให้ครูเค้าเดาว่าอันไหนน่าจะนำความร้อนได้ดีกว่ากัน พอเค้าทดลองแล้วก็ให้เค้าเปรียบเทียบกับกลุ่มอื่นถ้าผลออกมาไม่เหมือนกัน เรายังจะให้เค้าลองคิดดูว่าเป็นเพราะอะไร ถามเค้าว่าลองทำดูใหม่ดีมั๊ย I want to have the teachers do activities that they really want to do. After explaining the framework of the National Curriculum, the teachers might explore the activities based on their interests. We will set all materials out for them, but we don't need to prepare all materials for every group. Just set the materials for each activity at the back of the room. When they finish the activity, they should have time to share their results with other groups. If their results do not match with other groups, I would encourage them to think and redo the activity again. (Sommit, Card Sort Activity)

เราอาจจะพูดภาพรวมทั้งหมด พอถึงเวลาก็เป็นกิจกรรม ปล่อยแบบผึ่งแดดเลยใครอยากทำกิจกรรมอะไรทำเลย กลุ่มเดียวก็มี 3-4 lab มันก็ดีอย่างเสียอย่าง คือเราจะควบคุมชั้นเรียนไม่ค่อยได้ ครูเขาจะหลากหลายเดินเพนพ่าน เต็มไปหมด แต่ถ้าเราเอาที่ละกิจกรรม มันก็ดีอย่างคือสรุปเป็นเรื่อง ๆ แต่แบบนั้นใช้เวลามากก็ต้องดูครูก่อน ถ้าเขารับได้เร็วพื้นเขาดี เราก็คงพูดภาพรวมแล้วแบ่งให้เขาทำเลย อันไหนที่เขารู้แล้วกิจกรรมนั้น เขาไม่ต้องทำกิจกรรมไหนที่เขาสนใจ เขาก็ไปทำซึ่งเรามีอุปกรณ์ให้หมด สมมติเรามี 10-20 กิจกรรม กิจกรรมไหนที่เค้ารู้แล้วเค้าก็ไม่ต้องทำแล้ว บางกิจกรรมเค้าสนใจเค้าก็ต้องทำดู แล้ววิทยากรเดินตามกลุ่มอธิบายเป็นกลุ่ม ๆ

I will provide an overview of activities then I will allow them to do activities freely. The Pro is teachers will do the activities that they really want to do. In this case, we have 10-20 activities, they don't have to do all but decide which ones they want to do. The Con is we cannot provide knowledge of each activity to them. (Sommit, Interview #1)

Sommit believed that PD should provide activities and knowledge as much as possible. He explained that “it was like they were hungry, so it is our job to give them food. We [the professional developers] have to give them enough food to help them

survive. Then, it was their job to digest the food we give them.” Sommit explained that this analogy, in his opinion, represented the nature of PD, professional developers, and teachers. The teachers needed knowledge and information about teaching and learning science. The professional developers had a role in helping them to address their needs. After the PD, the teachers need to recall what they learned from PD and construct their own knowledge based on what they learned from the PD.

สิ่งที่เราให้ครูไปนี่มันเหมือนเราให้เขากินข้าวมีเท่าไรอัดๆให้เขาครบกินอย่างเดียวเลยหิว
ใจมาถึงก็ตักใส่ปากแล้วเหมือนกับควายกลับไปแล้วค่อยไปเคี้ยวเอื้อง ชะยอกออกมาย่อย
It’s like they are hungry so we have to put food in their mouths as much as possible. Then, similar to cows, they will put food back into their mouths from their stomach and chew it again (Sommit, Interview #2).

In summary, Sommit seemed to exhibit activity-driven and didactic orientations. However, these orientations were blurry, which led to his confused teaching during the PD implementation. He believed that during the PD, the professional developers should encourage teachers to think on their own. He did not want the teachers to follow his instructions or the activity instructions in the resource book. He was aware that this transformation might not occur immediately during the PD implementation. The teachers needed time after PD to construct their own knowledge of teaching and learning science. Sommit wanted the teachers to adjust all the knowledge and information they learned from the PD to their own teaching style. According to his orientations, Sommit introduced many activities and general knowledge for doing the activities. He rarely explained the scientific concepts because he believed that the teachers were able to find those facts in the PD manual or other resources. In addition, he liked to challenge the teachers into engaging in critical thinking. However, he did not follow up with the teachers to see if they were meeting his expectations. For example, Sommit threw questions to teachers without waiting for responses or other follow-up plans in order to

help teachers develop critical thinking skills. In regards to his goal in developing appreciation and thoughtfulness of teachers from doing activities, Sommit only let teachers to do the recommended activities and other activities that teachers were interested to do. However, he did not demonstrate other techniques to ensure how his goals could be met. Although Sommit adopted many strategies during the PD, he used them superficially. This led to the questions of to what degree the PD teachers would meet his goals.

PCK for PD

Knowledge of teachers' understanding of science. Similar to many professional developers, Sommit indicated that most of the private school teachers graduated in science education, in which they took many science courses. Thus, Sommit believed that the PD participants were already had good content knowledge in science.

ส่วนใหญ่คิดว่าน่าจะตรงแผนมากกว่าครูทั่วไป เพราะครูเอกชนเขาสามารถที่จะ เช่น ถ้าเขาต้องการครูวิทยาศาสตร์เขาก็จะรับครูวิทยาศาสตร์เข้ามา หรือถ้าเค้าต้องการครูคณิตศาสตร์เค้าก็เปิดรับครูคณิตศาสตร์ขึ้นมา แต่กรณีที่ครูเก่ามาแล้วเขาไม่มีครูเขาก็เอาครูที่เคยสอนอยู่เอาไว้หมุนเวียนกันสอนแทนซึ่งตัวนี้ก็เป็นปัญหาเหมือนของรัฐบาล แต่ราชการที่มีปัญหาที่ครูไม่จบตรงวุฒิที่เราต้องอบรมให้เขา แต่ครู สข. ก็มีส่วนหนึ่งจะตรงวุฒิ บางครั้งอาจจะวุฒิจบปริญญาโท หรือ ปริญญาเอกทางด้านวิทยาศาสตร์เคยมีมาเหมือนกัน
I think these PD teachers should have science education background when compared to the public school teachers. Some teachers graduated with master degree. I used to see some teachers with a Ph.D. also. (Sommit, Interview #1)

Sommit's belief about teachers' knowledge background led him to the decision to ignore providing content knowledge to teachers. Hence, Sommit emphasized developing teachers' laboratory skills because he believed that most teachers did not have correct laboratory skills when they studied at schools or college.

วัตถุประสงค์ของการอบรมครั้งนี้ในการเลือกกิจกรรมแต่ละกิจกรรมเพื่อหนึ่งมุ่งเน้นให้ครูพัฒนาทักษะในการทำกิจกรรมวิทยาศาสตร์ มุ่งเน้นทักษะการใช้เครื่องมืออุปกรณ์และด้านความรู้ครูสามารถไปเสริมได้เอกสารที่ให้ไปอยู่ในคู่มือ พยายามให้ครูได้ทำ Lab ให้มากที่สุดให้ครูมีความมั่นใจเพราะว่าครูบางคนไม่เคยทำ lab เลย หลอดทดลองไม่เคยจับสารเคมีไม่รู้ รู้แค่ว่าผสมกันแล้วเปลี่ยนสีแต่ว่าไม่เคยทำ lab เลยสมัยเขาเรียนเขาก็ไม่เคย

ทำ lab บางคนก็ไม่ได้จบด้านวิทยาศาสตร์ ที่จบสมัยก่อนก็ไม่ได้ทำ แต่พอมาทำ lab บางทีเขาก็ไม่มีความมั่นใจ ครั้งนี้เราคิดว่าให้เขาทำ lab แล้วเขามีความมั่นใจมันไม่ยากเกินไป อย่างที่คิดไม่อันตรายอย่างที่เข้าใจเขาน่าจะกล้าที่จะเอาไปเล่นกับเด็กที่ผ่านมาเขาไม่กล้า เพราะว่าหนึ่งเขาไม่รู้จะหาสื่อที่ไหน สองเขาไม่มีความมั่นใจในการทำกิจกรรม ส่วนประเด็นเนื้อหาจริงๆแล้วของเคมีมันไม่ยากเกินไปนัก คิดไปเองนะ ฟิสิกส์ก็คิดว่าของตัวเองไม่ยาก เคมีก็ว่าไม่ยาก อาจจะยากสำหรับครูก็ได้เราไม่รู้แต่ว่าสิ่งที่อยู่ในเอกสารครูเขาน่าจะอ่านและสรุปตรงนั้นได้แต่ว่าอยากให้ทำคือให้เขาลงมือปฏิบัติให้มากที่สุด

I select the activity that help teacher practice the laboratory skills and other skills that are necessary in learning science. I want teachers to do as many labs as possible because they didn't have adequate experience when they were at school or college. So, they don't have confidence in having students do labs. I think the chemistry concepts at primary level are not difficult. They shouldn't have problems. Rather, I want them to improve their lab skills. (Sommit, Interview #2)

Sommit displayed his knowledge about teachers' learning difficulties for concepts of chemical change and heat conduction. According to the chemical change concept, Sommit indicated that teachers generally did not know when the chemical reaction occurred, which led to their ineffective use of chemicals during the activities.

น่าจะเรื่องของ การเกิดปฏิกิริยาเคมีว่าตัวไหนที่เป็นตัวบวกว่าตัวไหนปฏิกิริยาตัวไหนไม่เกิดปฏิกิริยาเคมี แล้วจะเอาเกณฑ์อะไรมาวัดบางอย่างเราบอกว่าใช้สารนิดเดียว เขาไม่มั่นใจเวลาทดลองครูเขาจะใช้สารไปเยอะ ที่เรารู้เราใช้สารนิดเดียวมันก็เกิด แต่ครูเขาใส่สารไปเยอะทำให้สิ้นเปลือง มันยังมาถึงเรื่องของสิ่งแวดล้อม ความสิ้นเปลืองทางด้านวัสดุในการเรียนการสอน

Teachers don't have evidence in doing labs. They don't know how much chemical they should put into a reaction. So, they like to use excessive amounts of chemical to have the reaction occur, which is not good for the environment and wastes the chemical. (Sommit, Interview #1)

When asked about teacher learning difficulties on the heat conduction concept, Sommit indicated that he did not think teachers find this concept difficult to learn because teachers did not to learn on a molecular level in that heat is transferred from one molecule to another molecule.

ไม่แน่ใจถึงไหนเพราะส่วนใหญ่เรื่องการนำความร้อนที่เราสอนมา มันไม่ค่อยมีปัญหา มันเน้นในมาตรฐานนำความร้อนได้แตกต่างกันแต่นั้น แต่ว่าวิธีการนำความร้อนถ่ายทอดพลังงานผ่านโมเลกุลหนึ่งสู่อีกโมเลกุลยังไม่ถึง ส่วนมากเราจะใช้แท่งโลหะที่ขนาดใกล้เคียงกันมาทดสอบการนำความร้อน

I never have problems with the heat conduction concept because we only focus on the rate of conducting. We don't go to the concept about molecule yet. (Sommit, Interview #1)

Sommit also exhibited his knowledge about teachers' misconceptions on some scientific concepts.

เคยทดลองดูแล้วถามครูบ่อยๆ คือครูเค้าเข้าใจผิดตรงนี้ คือว่าเวลาเราเอาเกลือใส่ลงในน้ำแข็งทำให้น้ำแข็งละลายเร็วขึ้นหรือหลอมเหลวเร็วขึ้นหรือช้าลง ส่วนใหญ่ครูจะบอกว่าถ้าเอาเกลือใส่น้ำแข็งน้ำแข็งหลอมเหลวช้าลง มันก็ต้องเร็วขึ้น อุณหภูมิต่ำลงมันเป็นสมบัติของสารละลายอุณหภูมิจุดเยือกแข็งต่ำลงจุดเดือดจะสูงขึ้นครูบางคนเขาไม่ได้เรียนตรงนี้แต่เขามี Concept ว่ามันจะต่ำลง เพราะเขาไปเห็นถังหวานเย็น เมื่อถังหวานเย็นมันมีน้ำแข็งแล้วใส่เกลือลงไปมันทำไอศกรีมได้ แสดงว่าน้ำแข็งมันจะหลอมเหลวช้าที่จริงมันยิ่งหลอมเหลวเร็วขึ้น ซึ่งเด็กบางคนเขาก็ misconcept ด้านนี้อยู่ แต่เด็กบางคนที่มีโอกาสเห็นกิจกรรมของฝรั่ง ที่เวลาหิมะตกเขาเอาเกลือมาโรยเขาได้ Concept ตรงนั้น ตรงนี้เราก็จะชี้ยกตัวอย่าง เรอาบรมทุกครั้งจะยกตัวอย่างให้ครูเขาเห็นทุกครั้งตัวนี้บางทีเด็กก็เข้าใจผิด ถามครูหลายคนเขาจะต้องบอกว่าช้าลงเพราะว่าครุยึดติด Concept

Teachers have the misconception that when I ask putting salt in ice it causes the ice to melt slower or faster. They will say slower because they know the temperature will be lower. They don't know because they didn't learn it before so they cannot explain even though they see this phenomenon when they make ice cream. But, if we ask students in a country that has snow, they could be able to answer this because they see it. (Sommit, Interview #1)

อีกเรื่องของการชั่งวัตถุในน้ำ ถ้าชั่งทั้งระบบเอาก่อนหिनก่อนหนึ่งวางไว้บนเครื่องชั่งแล้วมี Beaker แล้วมีน้ำแต่ไม่ได้อยู่ด้วยกันเสร็จแล้วก็เอาไปชั่งแล้วพอเปลี่ยนใหม่เอาก่อนหिनใส่ใน Beaker ใส่แล้วเอาไปชั่งดูถามว่ามวลมันเปลี่ยนไหม ครูเขาบอกว่ามันจะเบาลง เพราะครูเขาติด Concept ว่าชั่งวัตถุในน้ำจะทำให้วัตถุนั้นเบาลงแต่นั้นคือเฉพาะวัตถุไงเค้าไม่ได้มองทั้งระบบพอครูไม่เห็นภาพตรงนั้นเราก็ต้องพยายามยกตัวอย่างแล้วก็ชี้ให้เขาเห็น They don't understand about the conservation of mass. For example, I ask them which circumstance will have more weight between putting a stone and a beaker with water on a scale or a beaker that contains the same volume of water and a stone. Teachers cannot answer this because they get stuck with the knowledge about weight of the object in water. They only think of the object separately rather than thinking of a whole system. (Sommit, Interview #1)

However, the interview and observation of PD implementation of Sommit revealed that although he had some knowledge about teachers' difficulties and misconceptions, he commonly lacked important knowledge necessary to help teachers overcome those difficulties. For example, Sommit decided to deliver the correct knowledge to teachers directly by either oral or written format rather than using any conceptual change strategies to help the teachers. In addition, Sommit did not display that he could respond

in appropriate ways when teachers exhibited misconceptions. He seemed to ignore the teachers' misconception of the concept and tried to push the task to the teachers themselves in order to find out the accurate knowledge on their own.

ในการเตรียมการสอนเราก็จะเตรียมเนื้อหาสอนนี้ให้มีอยู่ในคู่มืออยู่แล้ว ถ้าครูเค้าถามเราก็อธิบายบ้างสำหรับคนที่สนใจ แต่ที่สำคัญเราอยากให้เค้ารู้ว่าปฏิกิริยาเคมีมันมีทั้งข้อดีและข้อเสียเวลาเราสอนเราจะยกตัวอย่างปฏิกิริยาเคมีให้ทั้งข้อดีและข้อเสียโยงไปถึงชีวิตประจำวันให้เขาเห็นผลกระทบ เราพยายามอย่างน้อยครูก็ต้องรู้มากกว่าเด็ก บางอย่างถ้าเราให้ได้มากเราก็ให้เพิ่มเขาไป บางอย่างถ้าเราให้มากเกินไปครูก็รับไม่ได้การอบรมครู บางส่วนอยากจะได้เยอะ ๆ ถ้าบางคนรู้แล้วในส่วนนี้ บางคนบอกแค่นี้ก็เอาแล้วไม่ไหวอธิบายไม่ได้ จริง ๆ เราก็เตรียมไว้เยอะครูที่เขามานั้นพื้นเขาไม่เท่ากัน เราไม่รู้ Back Ground เขามาก่อน เรา Check ไม่ได้เรารู้แค่ครุมาเราไม่รู้หน้าตาเขาเป็นยังไง เรา Check ไม่ได้ว่าเขาจะอะไรมาทางที่ดีถ้าเราสามารถแยกได้ว่าพื้นฐานเขาเป็นเท่าไรเราสามารถจะให้ได้เนื้อหาเคมีที่สูงขึ้น พื้นๆ นี้เราไม่ต้องพูดถึงแล้ว

Most of activities that we have teachers do, we will provide content knowledge in the PD handbook. So, I won't answer all the questions that teachers ask me. But, I want them to recognize advantages and disadvantages of the chemical changes and how it connects to everyday experience. We try to help teachers to have knowledge more than students. But, the teachers don't have similar background and we don't ask for that information before they come to the PD. Sometimes we give content knowledge to them, but it is too difficult for some of them to understand when some of them can understand it. This is because they don't have similar background. (Sommit, Interview #1)

ครูเขาจะสังเกตเห็นว่ามันเกิดการเปลี่ยนแปลงแล้วเกิดสารใหม่ แต่ที่เราไม่ได้เน้นย้ำเรื่องของความร้อนเกิดสารใหม่มันต้องมีความร้อนเข้ามาเกี่ยวข้องกับมันเป็นปฏิกิริยาดูดหรือคายความร้อน ในเนื้อหาเราไม่ได้ให้ถึงขั้นนั้น ตรงนี้ครูก็ยังสับสนอยู่ว่าพอเราพูดถึงปฏิกิริยาดูดหรือคายความร้อน ครูเขาจะงงเวลาเดินตามกลุ่มครูเขาจะงง แต่ที่ไม่ให้ความรู้เพราะส่วนใหญ่ในเอกสารของเรามีเนื้อหาอยู่แล้วเพราะฉะนั้นคิดว่าครูเขาน่าจะไปอ่านเองได้

To teach the concept of chemical changes, many teachers get confused with exothermic and endothermic reactions. I know they don't understand it because I notice this when I walked to each group. But, I did not explain about this concept to them because this content is in the PD handbook so they can go back and read. (Sommit, Interview #2)

In addition, Sommit was the only professional developer who mentioned during the card sort activity that scenario drawing a picture of sugar in water would help the professional developers to understand the teachers' prior knowledge of the dissolution concept.

However, he put this scenario in the "not like me" group because he believed that the drawing technique might not be appropriate for the teachers.

ถ้าเป็นครูเอาไปสอนนี้ได้เพราะเด็กจะชอบวาด แต่ครูเค้าไม่ชอบวาดยกเว้นคนที่วาดเก่งจริงๆมันก็ดีเพราะเป็นการพยายามดึงความคิดครูกว่าถ้าหน้าแข็งหรือน้ำตาลใสในน้ำแล้วจะเป็นยังไง แต่ครูเค้าไม่ชอบวาด ถ้าสำหรับครูนะคิดว่าเราเอาน้ำตาลใสในน้ำแล้วสังเกต เราไม่ต้องบอกเค้าก็ได้ว่าเราจะสอนเรื่องการละลาย แล้วพอเค้าสังเกตแล้วเราก็อธิบายเค้าเรื่องการละลายและการเกิดสารละลาย จากนั้นเราก็มี animation การละลายของสารละลายจนสีว่าละลายยังไงซึ่งทำให้ครูเข้าใจมากขึ้นจริงๆ เทคนิคนี้ก็ดีแต่ครูไม่กล้าวาด

This technique can be used with the students because they like to draw. But the teachers are different from students. Only the teachers who are good at drawing will like this activity, but the other teachers will not do it. In the PD, I think it is better to let the teachers do the activity and ask them to observe that change. We may not tell them before observation what we are going to teach. After the activity, I will explain to them about the dissolution and solution concept. Then, I will use a CD animation to display the dissolution of Copper (II) Sulfate in water. I think these strategies may help teachers to understand better about these two concepts. (Sommit, Card Sort Activity)

Knowledge of PD strategies. Sommit overviewed his instructional sequence in the PD including providing knowledge to teachers about the Standards and its framework, allowing teachers to do activities, and providing necessary knowledge and techniques.

ส่วนใหญ่เป็นหลัก 5E ตามมาตรฐาน หรือเป็น Problem Solving บ้าง ก็จะมีตั้งคำถามแบบ Problem Solving บ้าง ซึ่งครั้งนี้คิดว่าน่าจะมีตั้งคำถามแบบ problem solving หรือยกตัวอย่างการแก้ปัญหา

I will use the 5E model of instruction as stated in the Standards. I will also use problem-solving strategy by asking questions to teachers to have them solve some problems. (Sommit, Interview #1)

However, during the PD Sommit did not either model or explicitly use the 5E model of instruction because he believed that teachers already understood about the 5E and also they learnt this strategy in other sessions prior his session.

โดยทั่วไปแล้วคนแรกในการอบรมหรือวิธีการ เราก็จะพูดถึงการสอนแบบ 5E พอมาถึงเคมีก็ได้เรียนเรื่อง 5E มาแล้วอาจจะพูดถึงว่าขั้นนำไปกิจกรรมนี้มีอะไรส่วนใหญ่ถ้าเราจะขึ้นสอนตัวอย่างเรื่องมีกิจกรรมเราจะถามเด็กว่าไง เราสอนครูโดยที่ครูไม่รู้ตัวว่าเป็นเทคนิคของเรา โดยที่เราจะถามครูก่อนนั่นคือกระตุ้นด้วยคำถาม ทางเราเองพยายามศึกษาว่าเขาจะเอาความคิดของเด็กว่าเขาคิดอะไรอยู่ เขามีอะไรอยู่ในหัว เขาออกมาให้ได้ก่อนเทคนิคตรงนี้ถ้าได้ตรงนั้นมาจึงจะเอาไปวางแผนการสอนได้ส่วนใหญ่มาถึงเราก็สอนๆ เลยโดยที่ไม่สนใจว่าเด็กเค้ารู้อะไรมาก่อน บางอย่างเด็กเขารู้มาแล้ว เราก็ไปสอน ถ้าเด็กรู้เรื่องนี้ รู้ไม่จริงรู้ผิดคลาดเคลื่อนเราก็ต้องแก้ตรงนี้ก่อนแทนที่จะสอนเรื่องอื่นเลย ครั้งนี้พยายามวางแผนเอาเทคนิคตัวนี้เข้ามาใช้ คือเทคนิคค้นหาความรู้ในตัวเด็ก อย่างคำถามหรือกิจกรรมที่เป็นค้นหาความรู้ในเรื่องนั้นๆอย่างไร ยกตัวอย่างเอาใบกิจกรรมอันนั้นมาทำมีที่เอามา

In general, the earlier sessions will introduce about the 5E model already. So, I will suggest to them only how to engage students, how to ask

students about this activity. I will use these techniques without telling them these are my techniques. I will encourage them with questions. I am interested in investigating students' thinking. Before teaching students, we need to know first what's in their head. In general, teachers like to teach every single thing even though students know it already. So, if they know it, we don't have to teach it again. But if they misunderstand it, we can help them understand it correctly. I try to tell teachers about these techniques and encourage them to use this technique with their students. (Sommit, Interview #1)

Sommit mentioned about using another strategy, such as problem-solving, in the PD.

Sommit displayed his knowledge on this strategy in that it initiated teachers' thinking more critically about the activities. During the PD implementation, it found that his instruction through the problem-solving strategy involved throwing out questions to teachers without any efforts in helping teachers become knowledgeable about this strategy or about the content knowledge.

ซึ่งตรงนี้เราไม่ได้อธิบาย ครูเขาเกิดปัญหาอีกหลายกลุ่ม ที่มีปัญหาเหล่านี้ ส่วนใหญ่ก็ไม่เคยเจอปัญหานี้บางครั้งก็มาเจอ ถ้าเราปล่อยให้ครูเขาคิด ถ้าครูเขาเกิดปัญหา เด็กก็จะเกิดปัญหา กระตุ้นให้มีกิจกรรมที่อยู่ในเด็กให้ช่างคิด ช่างสังเกตได้หลุดออกมาถ้าเราไปถามเด็ก ๆ เขาก็ไม่ตอบ เราก็เห็นพฤติกรรม ของครูทำอะไรแปลก ๆ ครูก็ไม่รู้นะเขาทำแล้วอธิบายก็ไม่ได้ ต้องไปค้นต้องไปถามผู้รู้อีกทีหนึ่ง เพราะว่าบางคำตอบเราไม่สามารถตอบเด็กได้ในชั่วโมงนั้น หรือบางที่เราอาจจะไม่รู้ก็ได้บางอย่างอาจเป็นเรื่องใหม่สำหรับครู เราก็ต้องลองแล้วไปค้นซึ่งมันมีคำตอบอยู่แล้ว

Many groups of teachers have the same curiosity about this activity, which I let them think. If teachers have curiosity, students will have this curiosity, too. I know teachers don't know the answers, so I tell them to ask experts or find answers in the texts. Sometimes we could not give answers to students immediately or we may not know the answer. So we have to tell teachers to find out the answer. It already exists somewhere (Sommit, Interview #2).

The excerpt above reveals that a lack of pedagogical content knowledge including purposes of the strategy, and knowledge of teachers' learning science was linked to the ineffective use of strategies. It is also evident that Sommit's use of problem-solving strategy was influenced by his beliefs about roles of teachers and himself in the PD-- teachers had to take their own responsibility in finding the knowledge. He believed that

knowledge already existed, which could be found anywhere. His goal for using this strategy was to encourage teachers to see the importance of reasoning and critical thinking skills and then use this technique with their students.

แต่วิธีใหม่ครูเขาจะถามเอง เด็กเขาก็จะถามเอง คิดว่าอันนี้น่าจะประสบความสำเร็จที่เรากระตุ้นให้เด็กกล้าถามขึ้นมาแล้วเด็กคิดว่าเพราะอะไรตรงนี้น่าจะโอเค คือว่าน่าจะเป็นผลสำเร็จในการกระตุ้นให้ครูหรือเด็กคิดขึ้นมาได้ ซึ่งการคิดหรือตั้งคำถามนี้คำตอบมันอาจจะยังไม่ได้มันก็ต้องไป find out อีกทีหนึ่ง อันนั้นคือสิ่งที่เราอยากจะให้ทำ
With this method, teachers or students will have questions. I encourage them to ask questions, which means they are thinking. But, they have to find out the answers on their own. (Sommit, Interview #2)

Also, Sommit did not either explicitly model science teaching to teachers nor explain and help teachers to connect the PD strategy to the classroom strategy. This made me question how much and to what degree Sommit's knowledge bases for PD, such as knowledge of students' and teachers' learning, classroom and PD strategies, and context of changes of teachers' teaching behavior were connected. He provided much information, such as students' prior knowledge and teaching techniques, but he did not make explicit to teachers how these chunks of knowledge were important to classroom teaching.

Knowledge of PD curriculum. Sommit indicated that the PD curriculum contained everything that teachers could use for their classroom teaching--activity directions, worksheets, materials needed, and knowledge for teachers. He indicated that the curriculum was designed in a general way, which contained knowledge that teachers needed to know. Thus, he, and also other professional developers, did not redesign the curriculum to fit with the needs of these particular PD participants. However, he indicated that he prepared himself in terms of content knowledge, and teaching approaches for these teachers because they had better knowledge than the public school teachers.

หลักสูตรนี้เราวางแผนทุกๆ ไปเลยว่าครูประถมควรจะต้องรู้เรื่องนี้ เรื่องนี้ เสร็จ แล้วครูประถมยังต้องรู้เรื่องอะไรบ้าง เนื้อหาอะไรบ้าง แต่วิธีการไปอบรมเนี่ย วิธีการอาจจะแตกต่างกัน ความเข้มของเนื้อหาจะแตกต่างจากครูทั่ว ๆ ไป คิดว่าอย่างนั้นการเตรียมตัวเราจะเตรียมตัวหนักขึ้นเพราะว่าครูที่มาเขาค่อนข้างที่จะเก่ง เพราะฉะนั้นเราต้องเตรียมตัวให้หนักเป็นที่ไว้วางใจของครูเขา ยอมรับในความสามารถของกลุ่มเราด้วยสำหรับเราคงจะไม่ดำนาน่าๆ ไม่ได้

We designed a curriculum by talking to each other about what we want primary teachers to know and what contents or activities that primary teachers need to know. So, this curriculum is appropriate to every primary teacher in terms of content and activities. However, the teaching approach during the PD will be different depending on teachers. For example, I will prepare myself for teaching these private school teachers more than teaching the public school teachers because they know more than the public school. So, I have to be solid. (Sommit, Interview #1)

Although Sommit believed that the PD curriculum and IPST curriculum covered all requirements stated in the Standards, he did not know whether or not teachers appreciated this curriculum and used it in their classroom.

แต่ถ้าโรงเรียนที่ไหนเคยเห็นหนังสือเรา เคยใช้หนังสือเราใช้หลักสูตรเราแล้วก็จะดี เพราะนี่ข้อนี้คือข้อเสียของโรงเรียนหลายที่ที่เขาไม่ได้หนังสือเรา เพราะว่าเอกชนเขาเข้าไปขาย เพราะหนังสือของเอกชนเขามีแต่ content เขาไม่มี lab เพราะฉะนั้นบางที่เราพูด lab เขาจะมีความรู้สึกว่าเขาไม่คุ้นเคย แต่จริง ๆ แล้วสิ่งที่เราทำได้ทำ ทำแบบสรุปเสร็จแล้วเด็กเค้าจะได้ครบ เขาจะได้สรุปความคิดรวบยอดออกมา แต่แบบเดิมมันก็จะป็นเนื้อหาอธิบาย เขาไม่ทำกิจกรรมเพราะฉะนั้นก็เลือกเอาว่าทำแบบไหน ทำแบบเราได้ concept เสียเวลาหน่อยแต่ว่าเด็กรู้ประเด็นที่จะจุดประกายอะไรให้เขาเออะเอะ แต่ถ้าแบบเดิม คือสอนให้เขาท่องจำซึ่งเราพบแล้วว่าวิธีนั้น ไม่ทำให้เด็กเกิดการเรียนรู้ เด็กได้จำอย่างเดียว ไม่ให้เด็กเรียนรู้ไม่เกิดความคิดสร้างสรรค์ขึ้นมา เราว่าครูหลายคน ไม่ยอมเปลี่ยนวิธีการสอนสองมาเพื่อรู้ว่าเราจัดการเรียนการสอนยังไง แต่เราไม่สามารถรับประกันได้ทุกคนว่าครูที่มาต้องไปสอนตาม Model ของเรานะ เรายังคับไม่ได้ โรงเรียนให้สอนแบบเดิมใช้เนื้อหาอย่างเดียว อันนี้ค่อนข้างลำบาก ถึงแม้เราสอนแบบนี้ ถ้าโรงเรียนไม่ได้ใช้หนังสือของเราเอง เขาใช้หนังสือเอกชน เป็นแบบ Chalk and talk เนื้อหาเขียนไว้หมดแล้ว ไม่มีให้เด็กคิด ครูเขาสอนแบบนั้นซึ่งเราแก้ไม่ได้ มันก็เลยไม่รู้ว่าคุณครูเขาได้เอาความรู้ไปใช้ประโยชน์จริง ๆ หรือเปล่า

It is good if teachers use our curriculum at school because our curriculum has all they need including, content knowledge and activities. The curriculum of a private company will contain only content knowledge, which use a “chalk and talk” teaching style. Teachers don’t have activities for students so students don’t have opportunities to develop their creativity. For this PD, we will model how to use our curriculum in teaching science. However, we cannot guarantee that teachers will use our curriculum and we don’t know they really use our curriculum and methods. (Sommit, Interview #1)

Knowledge of assessment of scientific literacy. Sommit demonstrated that he did not agree with assessing teachers’ learning during the PD. In addition to the time

restrictions to assessment processes, Sommit believed that teachers would not fully develop understanding on the concepts that they learned during the PD, but they need several times to recall their PD experience and then construct knowledge. Further, his view to PD, as a warehouse and the teachers' learning as a cow ruminant, shaped his knowledge of assessment in the PD.

จังหวะที่จะประเมินผลโดยมันยังไม่ย่อยเลยประเมินไม่ได้แล้วรูปแบบไหนที่จะไปประเมิน มันน่าท้าทายเหมือนกันที่จะให้ครูมาอบรมแล้วประเมินประเมินยังงีก่อนเขากลับหรือ ประเมินหลังจากเขากลับไปแล้วจะเอาอย่างไรให้มันมีความยุติธรรมกับทุกคนเพราะฉะนั้นถ้า เขากลับส่งแบบสอบถามไป เราก็คงไม่รู้ว่าเขาตอบจริงหรือเปล่าเขาให้ใครตอบแล้ว ระยะเวลาในการตอบเพียงแคให้ตอบคำถามประเด็นกว้างๆเราดูการวิเคราะห์หรือการ อภิปรายของเขาว่าครูเขามีความคิดอย่างไรอาจจะสร้างเป็นประเด็นไปให้เขาแล้วให้เขา วิเคราะห์เป็นประเด็นเราก็คงคิดเหมือนกันว่าเราจะทำอย่างไรถึงจะประเมินครู ถ้าจะสอบครูเขา จะเครียด จะเกร็ง แล้วจะอบรมแบบไม่มีความสุข อยากให้เขามีความสุขในการอบรมครั้งนี้ มากกว่า ถ้าครูสอนเด็กแล้วครูไปขู่เด็กว่าเดี๋ยวจะมีการสอบแล้วเอาผลสอบเป็นการตัดสิน เด็กเด็กเกิดความเครียด ท่านองเดียวกันถ้าย้อนกลับถ้าเรามาทำกับครูครูก็อาจจะเกิด ความเครียดอยากให้ครูมีความสุข ทำไปได้ซักถาม มันก็ได้อย่างเสียอย่าง แต่ให้รู้วิธีการ ว่าทำอย่างไร

I think it isn't fair if we assess teachers when they don't digest the information we give them yet. When the assessment should be is a critical question because if we assess them right away, they will use their prior knowledge to do the testing. But, if we do it after PD, how do we know they do it themselves. In addition, teachers will be too stressed when they know they will be assessed, which I don't want. I want them to enjoy the PD. (Sommit, Interview #1)

Sommit believed that assessing the teachers' understanding right after the PD might not be sufficient because the teachers did not have enough time to transform and absorb what they learned from the PD yet. In addition, it was very difficult to evaluate whether or not the professional developers succeeded in the PD by testing the teachers. In addition, Sommit mentioned that it would complicate the work of the professional developers to design a good test that assesses all of the knowledge that the teachers should have. In other words, Sommit indicated that when the teachers did not get the right answer on some test items, it did not mean that they were unknowledgeable or the

PD was not effective. The teachers might know other things that were not asked on the test.

ที่จริง 2 วันครึ่ง ถ้าสอบเสร็จแล้วจะประเมินยังไง ประเมินไม่ได้ เราคิดว่าเราไปเรียนหนังสือ 3 วันแล้วสอบเลยมันคงยาก สิ่งที่เขาทำได้ดีคือเอาความรู้เดิมมาตอบถ้าตอบถูกก็ไม่ได้หมายความว่าเราสอนดี หรือว่าเขาตอบผิดก็ไม่ได้แปลว่าเราสอนไม่ดี ข้อสอบแค่นั้นที่มันจะคลุมเนื้อหาที่เราให้ละ ประถม 6 ชั้นปี 8 สารเสร็จแล้วเราจะประเมินผลยังไง เพื่อคลุมว่าเขารู้หมดข้อสอบของวิทยากรคนละข้อก็ 7 ข้อ ข้อสอบคงไม่เป็นchoice คงอธิบายข้อหนึ่งใช้เวลาก็นาทีถ้าใช้เวลา 5 นาทีครูคงอธิบายไม่ได้อย่างน้อย 10 นาที ในการอภิปรายในการตอบข้อสอบอัตโนมัติ 5 คนก็ชั่วโมงนึง เราก็ต้องมาตรวจแล้วเกณฑ์ที่จะตรวจตรวจแล้วคนนี้จะคะแนนมาก คนนี้จะคะแนนน้อย คะแนนจะแปลความหมายว่ายังไงแปลความหมายว่าเราสอนดี เราสอนไม่ดี หรือเด็กความรู้ดี ความรู้ไม่ดี ซึ่งมันก็บอกไม่ได้ครูเขาอาจจะมีความรู้ก็ได้แต่บังเอิญที่เราถามแค่บางจุดที่ครูเขาตอบไม่ได้แต่ความรู้ทั้งหมดเขาอาจจะดีก็ได้ ยกเว้นข้อนั้น เพราะเราไม่ได้ถามทุกเรื่องทุกจุดประสงค์ที่จะสอบวัดผลต้องถามทุกจุดประสงค์ที่เราจะสอนซึ่งยากพอสมควร

To do that, the test might be designed to cover every single concept in the single grade level, which I think it was not possible for a 3-day PD project. Otherwise, the testing could not tell whether or not the PD was successful since the teachers might not know the items in the test while they knew other parts that were not in the test. Furthermore, the testing should not be a multiple choice testing. That means we have to develop a scoring guide. The problem is what criteria leading [to use to determine] “good” or “bad” scores. It’s difficult. (Sommit, Interview #2)

In summary, Sommit displayed limited PCK for PD. Although he indicated he knew about teachers’ misconceptions of some concepts in chemistry, he did not display knowledge in helping teachers to overcome those misconceptions. Sommit believed that teachers’ learning occurred after they left the PD. Teachers had to digest all the information that they had from the PD and develop their own understanding. In addition, Sommit believed that science knowledge is facts that teachers could find from books or asking people. Thus, he did not focus on providing content knowledge to teachers. Sommit mentioned about the 5E and problem-solving strategies. However, he did not explicitly show his understanding about how those strategies valued teachers’ learning. Similar to Vimon, Sommit did not agree with providing testing to teachers. He indicated that he did not know how to design the test that would provide accurate results about whether or not the PD helped teachers to increase their understanding of science.

The Cross-Case Analysis of Professional Developers' Implementation, Orientation, and PCK for Professional Development

The observation of PD implementation of all professional developers through an entire PD project revealed that, in the PD sessions, the professional developers talked about 90% of the time with very little input by the participants. The data reveals that the professional developers believed science as information that was there to be discovered and that science instruction means helping the learners to discover this body of information through activities, experiments, or telling from teachers. The professional developers believed that sometimes doing activities alone could not help teachers to understand the scientific concepts. Thus, the professional developers had to provide accurate science knowledge to teachers either by oral or in print. All professional developers indicated that the PD handout that they gave to teachers contained clear information and background knowledge for each activity. Thus, the teachers would be able to find out information on their own in the PD resource book anytime they wanted.

Although the professional developers indicated that they would provide opportunities for the class discussion, the observation revealed that there was little opportunity for the teachers to share their ideas. The professional developers did not question the PD participants much and the communication during PD implementation was mostly one way. In other words, the PD participants were mostly passive recipients of information and the professional developers maintained their role as lecturer. In addition, the professional developers' questions, discussions, and teaching strategies failed to check PD teachers' comprehension. The professional developers' questions were designed to lead toward their expected answers. Their questions were closed and subject-

centered and did not prompt the teachers' critical thinking. The professional developers offered few opportunities for the PD participants to communicate orally. For example, although some of those professional developers, such as Piti and Somsri, focused on modeling using the 5E teaching strategy in the science classroom, during the explanation step, they provided few opportunities for the teachers to communicate their findings. They only asked one or two groups out of 10 to share their findings from the activities.

Furthermore, all professional developers believed that the PD participants who were from private schools had better science knowledge than the teachers from public schools because the private schools could hire teachers who had a background in science education. The professional developers believed that the teachers in the private schools might have different needs from the teachers in the public schools. However, the professional developers did not design a new PD curriculum that best served the needs of these PD participants. They report that the amount of activity, scientific knowledge, and teaching strategies they used in this PD project were essentially the same as the previous PD that they provided to the public school teachers.

The observations of PD implementations also showed that the professional developers paid less attention to assessing teachers' learning. This may be because all of the professional developers believed that the PD participants already knew the science content that they were teaching in the primary grades. When I asked them how they would know if the teachers learned during and at the end of their session, all of the professional developers brought up the idea of summative evaluation. According to them, the evaluation of teachers' learning would be impossible for the PD because of the time constraint. Some professional developers, such as Piti and Sommit, indicated that the

teachers' questions during the activities could provide them with an idea of whether or not the teachers understand or develop any knowledge throughout the PD. Furthermore, some professional developers mentioned that if the teachers did the activities on their own, they would understand that concept. In addition, the PD also provided a PD manual, which contains clear explanations of each activity. Thus, the teacher would be able to review the manual at their convenience. It was also interesting when Vimom indicated that she did not agree that teachers should take tests before and after PD, it was because she did not want the teachers to view testing was important in teaching and learning. She believed that the teachers should alter the way in assessing students' learning to be more authentic.

The remaining of this chapter presents the 4 assertions that I developed from the data in order to answer my research questions.

Assertion 1: The Individual Professional Developers Displayed Multiple Orientations which were Internally Related. These Orientations Deviated from the Reformed Science Education Standards.

All professional developers in the study reflected multiple orientations, which complicated the research. These orientations included activity-driven, didactic, and pedagogy-driven orientations. The majority of professional developers shared activity-driven and didactic orientations although two professional developers, Piti and Somsri, held a strongly pedagogy-driven orientation. Table 11 shows the orientations for PD that each professional developer displayed.

Table 11

Orientations of the Individual Professional Developers

Professional Developers	Orientations
Piti	Pedagogy-driven, Didactic, Activity-driven, and Discovery-driven
Vimon	Activity-driven and Didactic
Somsri	Didactic, Pedagogy-driven, Activity-driven
Sommit	Activity-driven and Didactic

Activity-driven orientation. To support this claim, all professional developers tried to cover the PD activities that they planned for the PD. For example, Vimon had a strong activity-driven orientation. She provided many activities in order to encourage the teachers to try those activities with their students. She did not seem to be concerned about whether or not the activities developed coherent understanding of the scientific knowledge and purposes of activities. Sommit also demonstrated the activity-driven orientation during the PD implementation. After his introduction of Science Education Standards and the chemistry concept map, he allowed the teachers to do the activities independently. The teachers could decide which activity they desired to do and which activity they did not want to do. Sommit did not pay close attention to whether or not the teachers developed the important concepts and/or understood the purpose of the activities. Piti's implementation in the PD demonstrated partly an activity-driven orientation as well. Although Piti did not provide as many activities as the other professional developers, he did not explicitly help the teachers to conceptually understand the purpose and the critical aspects of the activities. His purpose for the PD was to model science teaching. Thus, Piti selected activities in which he was able to model all of the 5 steps of the 5E model of

instruction. Piti allowed the PD participants to do hands-on activities and reminded the teachers what he had done in terms of teaching techniques.

The professional developers also believed that they should provide opportunities for the teachers to do many activities in order to increase the teachers' confidence in implementing those activities with their students. In addition to developing teachers' confidence, the professional developers indicated that direct experiences in doing activities helped the teachers realize why they need to provide these experiences to the students as well.

พยายามให้ครูได้ทำ Lab ให้มากที่สุดให้ครูมีความมั่นใจเพราะว่าครูบางคนไม่เคยทำ lab เลย หลอดทดลองไม่เคยจับสารเคมีไม่รู้ รู้แค่ว่าผสมกันแล้วเปลี่ยนสีแต่ไม่เคยทำ lab เลยสมัยเขาเรียนเขาก็ไม่เคยทำ lab บางคนก็ไม่ได้จบด้านวิทยาศาสตร์ ที่จบสมัยก่อนก็ไม่ได้ทำ แต่พอมาทำ lab บางทีเขาก็ไม่มีความมั่นใจ ครั้งนี้เราคิดว่าให้เขาทำ lab แล้วเขามีความมั่นใจมันไม่ยากเกินไปอย่างที่คิดไม่อันตรายอย่างที่เข้าใจเขาน่าจะกล้าที่จะเอาไปเล่นกับเด็กที่ผ่านมามาเขาไม่กล้าเพราะว่าหนึ่งเขาไม่รู้จะหาสื่อที่ไหน สองเขาไม่มีความมั่นใจในการทำกิจกรรม

I wanted the teachers to do many activities as much as possible because some teachers never had experiences in doing laboratory. They did not have science background. So, they were afraid and lacked confidence to implement the activities with their students. (Sommit, Interview #2)

Didactic orientation. The professional developers also displayed a didactic orientation. In general, all professional developers maintained their role as a lecturer during the PD implementation in order to provide explanations of the results, conclusions, and scientific knowledge for each activity. The clearest example of didactic orientation was Somsri. Somsri explained and provided scientific knowledge for every PD activity although she did not have the teachers do those activities during PD implementation. For the activities that Somsri had the teachers perform, she discussed the activities and shared the correct answers and explanations. However, on the activities that the teachers did not do, Somsri directly informed the teachers about the purpose, conclusion, explanations, and scientific concepts of those activities.

เด้าก็อาจจะได้วิธีการสอน ได้เนื้อหาได้การทำกิจกรรม อาจจะช่วยแก้ปัญหาการทำกิจกรรมให้เขา แล้วก็วิธีสอน เราก็ไม่แน่ใจว่าเขาจะเก่งกว่าเราหรือเปล่าแต่เราก็จะให้เขาวิธีสอน การอภิปราย สรุปผลการทดลอง เทคนิคต่างๆ

The teachers will learn teaching strategy, content knowledge, and activities. We also help them with the problems they have in the classrooms. I am not sure whether or not they know better than us. But, we will train them anyway about teaching techniques, explanations, conclusions of activities, and other important techniques. (Somsri, Interview #1)

Somsri was not the only one to display this orientation. The other professional developers also gave facts to the teachers, especially in regard to the scientific concepts that they did not perform with hands-on activities. For instance, Piti only spent a few minutes talking and allowing the teachers to do a frequency activity, although he stated that this concept was the most difficult concept in the sound unit at the primary level. When Piti introduced this activity, he did not seem to expect that the teachers would conceptually understand the frequency concept, because he believed that this concept could not be taught by the 5E model of instruction or inquiry teaching methods to develop teachers' and students' understanding. He indicated that for this abstract concept, it was necessary to use other teaching strategies, such as directly telling the teachers, and also the students, frequency is and what its impact on human hearing.

Pedagogy-driven orientation. This orientation was the major orientation of two professional developers, Piti and Somsri. Piti displayed a strong pedagogy-driven orientation. He believed that the teachers should be able to develop their teaching ability if they had opportunities to see good examples of teaching science. Piti also indicated that the primary teachers normally did not have many experiences in learning science. They also did not take courses about primary science teaching methods that aligned with the reformed science education when they were in college. Thus, the teachers did not have good examples of how science should be taught in the classroom. Piti determined that his

goal for the PD was to help the teachers address this need. During the PD design, Piti selected the activities in which he could model the 5E model of instruction. During the PD sessions, Piti kept reminding teachers about the teaching techniques that he used with them before, during, and at the end of each activity.

Somsri also displayed a pedagogy-driven orientation. However, her PD implementation, shaped by orientation, was different with from Piti's. Somsri kept emphasizing that teachers needed to have an accurate understanding about scientific information and laboratory skills in order to be able to instruct their students when they were asked. Somsri also implicitly modeled the traditional role of teachers in that the teacher should be the "container" of knowledge for the students. During PD implementation, Somsri asked the teachers to closely follow the activity instructions, whereas Piti did not. Somsri explained the scientific knowledge of every single activity to the PD teachers, whereas Piti sometimes challenged the teachers to develop their own explanations. Thus, although Piti and Somsri shared a pedagogy-driven orientation, their pedagogy used in the PD was completely different from each other.

How the Multiple Orientations Fit within Individual Professional Developers.

Although the professional developers had multiple orientations to PD, which influenced their implementation in the PD, these orientations fit together and sometimes they were blended together. As in Piti's case, he strongly displayed a pedagogy-driven orientation. In addition, he also exhibited activity-driven, didactic, and discovery orientations. In teaching a topic such as "sound," one of four orientations that Piti had might play a dominant role another orientation might play a dominant role in teaching other concepts. For example, in regards to teaching the concept that that sound is produced by vibration,

the orientation that played a dominant role in implementation was the pedagogy-driven orientation, because Piti believed that he could demonstrate the 5E model of instruction to teachers when they were engaged in the PD activity. In addition, Piti believed that most of teachers did not have difficulties to learn this concept—that this concept would be easy enough for teachers to develop understanding by reading the PD handbook. During the activity, the discovery orientation played role when Piti encouraged teachers to do the activity in order to discover how the sound is produced. However, when Piti had to teach the concept of frequency to teachers, his orientation changed from pedagogy-driven to didactic, which led to the use of a different teaching approach. Piti decided to provide knowledge directly to teachers because he believed that this concept was difficult for teachers to develop understanding by doing an activity or reading in the PD handbook.

อันนี่คือกระบวนการสืบเสาะหาความรู้ เอาละจบไปแล้วเรื่องกระบวนการเรียนการสอนต่อไปเป็นเรื่องที่ต้องแนะนำ คือเรื่องของความถี่

What I just demonstrated was the inquiry process. Now, we finished talking about the process of teaching and learning. Next, I will talk about a topic that needs to be directly informed. That is the frequency topic. (Piti, PD Implementation)

ความถี่เป็นเรื่องที่เด็กเค้าทดลองเองไม่ได้ ทำได้แค่ว่าสั้นเร็วเป็นอย่างไร สั้นช้าเป็นอย่างไร มีการทดลองคือเราจะใช้ไม้บรรทัดวางกับขอบโต๊ะแล้วตีตูดู ฟังเสียงด้วย หรือถ้าจะดูสั้นเร็วก็เอาไม้บรรทัดมาโบกๆ ดูก็ได้ แล้วก็เอาดินน้ำมันมาแปะไว้แล้วโบกดูอีกที สิ่งที่สรุปได้คือของที่สั้นเร็วนั้นใน 1 วินาทีจำนวนรอบที่สั้นจะเยอะ ส่วนของที่สั้นช้าจำนวนรอบที่สั้นก็จะน้อย อันนี้ต้องให้ความรู้ว่าจะจำนวนรอบที่สั้นต่อ 1 วินาทีเรียกว่าความถี่ มีหน่วยเป็นเฮิรตซ์ ส่วนใหญ่จะเป็นความรู้ในส่วนนี้ อย่างมนุษย์ได้ยินเสียงที่ความถี่เท่าไร อันนี้ก็ต่อให้ความรู้กันโดยตรง

The students cannot do experiments on this concept. What they can do is to observe a ruler vibrate fast or slow. We have that experiment by placing a ruler on the table and pressing at the end of the ruler. Then, moving the ruler ahead and doing the same thing. Or, we can hold the ruler and make it wave. Then, we put play-do at the end of the ruler and wave it again. The students can observe how fast the ruler waves with and without play-do. Then, the teachers tell the students that the number of time the ruler move back and forth in 1 minute is called frequency. (Piti, PD implementation)

In Vimon's case, she exhibited two orientations including activity-driven and didactic orientation, which fit together. Based on the beliefs of Vimon, teachers, especially these particular PD teachers, already had good content knowledge in science. In addition, she believed that teachers would develop understanding and also correct their misconceptions when they did the activities. Furthermore, Vimon believed that the teachers came to PD because they needed to know many activities in order to use them with their students. Hence, the activity-driven orientation played a dominant role in Vimon's design and implementation for the PD. Vimon tried to introduce as many activities as possible to teachers with less attention to teachers' understanding of the concepts. The didactic orientation played a secondary role in her design and implementation for the PD. Vimon believed that content knowledge could be transmitted through textbooks, other written resources, and direct explanation. Thus, Vimon ended her session by providing a PowerPoint presentation about the content knowledge and its application to teachers. She also indicated that teachers could refresh their existing knowledge by reading the PD handbook or teacher-guided book.

In regards to Somsri's case, she displayed a combination of activity-driven, pedagogy-driven, and didactic orientations. Somsri strongly displayed a didactic orientation. She also exhibited process and pedagogy-driven orientations. The didactic orientation played a dominant role in PD design and implementation for Somsri. Somsri believed that teachers should be knowledgeable persons who possessed knowledge for answering and guiding the students in the activities and explanations. Teachers should be able to instruct or tell students whenever they had problems or questions. Based on her orientations, Somsri always emphasized, the importance of science knowledge, activity

techniques, and pedagogical knowledge. She often used the statement: “You need to know this in order to be able to tell your students.” In addition, she believed teachers should be able to perform activities using scientific laboratory skills correctly. According to these beliefs, Somsri allowed teachers to perform activities and she ended each activity by presenting information and knowledge of every single PD activity to teachers. The didactic orientation played a role over the activity-driven orientation when Somsri preferred to provide knowledge to teachers rather than giving time for them to do the investigation when the time is rushing. Somsri decided to warn teachers to finish their activities, and then she could give the correct answers of the questions on the worksheet and knowledge of the topics to the teachers. The pedagogy-driven orientation played the third role in this PD because Somsri only selected some activities to fully model the 5E teaching strategy at the beginning of her session. After she fully demonstrated the 5E model, Somsri kept reminding teachers about each phase of this model and mentioned to teachers about teaching techniques that teachers could use with students without modeling them to teachers. The didactic orientation played a role over the pedagogy-driven orientation in that although Somsri modeled how to teach science in the spirit of reform, she also held a teacher-centered view. Somsri was aware that the teachers might allow the students to explore the hands-on activities or get the students involved in a science lesson beyond the traditional way of teaching. However, she explicitly modeled that the teachers still had the primary role of lecturing the knowledge to the students, as seen in the way she gave explanations for all of the activities that the teachers were doing. Somsri’s orientations to PD might not be consistent when she expressed that implementing the 5E model of instruction in the PD was a waste of her time when she

would rather introduce to the teachers the hands-on activities and explain the content.

This concern led her to express that she might redesign the future PD to not fully model the teaching strategy.

สาขาต้องการให้ทุกสาระมีการแสดงการสอนที่ Inquiry ครบ 5 ชั้น ก็แล้วแต่สาระจะเลือกกิจกรรมไหน ซึ่งกิจกรรมนี้มันสามารถครอบคลุมเนื้อหาตั้งแต่ ป1 – ป3 ครอบคลุมได้หมดเลย เราก็เลยจัดอันนี้ แต่ทีนี้ถ้าจะแสดงการสอนให้ครบทุกชั้นตอน ซึ่งครวก่อน ๆ ไม่ได้แสดงกันขนาดนี้ แต่คราวนี้แสดงจนครบ ก็เลยทำให้เสียเวลา เพราะฉะนั้นคิดว่า ครวหน้าถ้าจะอบรมใหม่ คิดว่าเราไม่ต้องเอาให้ครบชั้นแล้ว มันไปทำให้เนื้อหาส่วนหลังที่มันสำคัญกว่า มันเสียเวลาไป เพราะครวหน้าคิดว่าจะต้องลด ให้เขาทำนิดหน่อย แต่ไม่ต้องครบทุกชั้นตอน คิดว่ามันจะช่วยให้มีเวลาพอสำหรับเรื่องข้างหลัง เพราะเรื่องข้างหลังมันเร่งมาก

The PD team wanted every session to model inquiry teaching. We independently designed what activities we would use for the demonstration. We modeled a portion of the 5E model of instruction in the previous PD but [modeled] every step for this PD. I think it wasted time because we had to rush at the end of the session. I won't use this strategy again in the next PD. I may allow the teachers to experience in some steps of the 5E model of instruction then move to the next activities. (Somsri, Interview #2)

According to Sommit's case, he held blurry activity-driven and didactic orientations. Sommit displayed the latter orientation, believing that science knowledge is facts that can be transmitted through reading the textbooks or direct explanation from experts. These two orientations were fit together when the activity-driven orientation played a dominant role in design and implementation of the PD over the didactic orientation. For example, in teaching the chemistry topics in the activity manual, Sommit encouraged teachers to perform the activities in order to verify the science concepts. Although he exposed teachers to the information and awareness related to those concepts, he did not provide adequate efforts in helping teachers develop understanding of the concepts from the activities. This related to his beliefs that knowledge could not be developed directly from doing the activities. However, the activities provided windows for teachers to discover the ending results of the activities, which teachers could later

verify with the factual knowledge in the textbook, and then construct to their own understanding. The didactic orientation played a secondary role when Sommit demonstrated that he had a role in providing knowledge that was not written in the PD handbook, such as teaching techniques and application of knowledge that related those activities to teachers.

Considering the Orientations of Professional Developers in Light of the Reformed Science Education. The activity-driven orientation of the professional developers drove their PD design and implementation in providing hands-on experience that similar to classroom activities to teachers. This orientation fit with the reformed National Science Curriculum Standards (2003) in that the standards request teachers to change their science teaching from rote learning toward inquiry by providing more opportunities for students to develop investigations in science classroom.

กระบวนการเรียนที่ผู้เรียนจะต้องสืบค้น เสาะหา สืบค้นตรวจสอบ และค้นคว้าด้วยวิธีการต่างๆ จะทำให้ผู้เรียนเกิดความเข้าใจและเกิดการรับรู้ความรู้ที่นั้ได้อย่างมีความหมาย
Learning process is a process that learners have to investigate and research for information through various methods in order to develop meaningful knowledge. (Standards, p. 219)

During the PD, some professional developers provided a few opportunities for class discussion. The professional developers tried to use questions, discussions, and engagement techniques to encourage teachers to perform investigations, but these opportunities were rare.

In comparing the cases with the Science Education Standards, there were instances when the cases deviated. The Standards indicate that sustainable learning occurs through a variety of learning processes, which include the inquiry process, rather than by telling.

ก่อนที่ครูผู้สอนจะจัดการเรียนการสอนในห้องเรียน จะต้องตระหนักว่าการเรียนรู้เกิดขึ้นด้วยตัวของผู้เรียนเอง การเรียนรู้เรื่องใหม่จะทีพื้นฐานมาจากความรู้เดิม ฉะนั้นประสบการณ์ของนักเรียนจึงเป็นปัจจัยสำคัญต่อการเรียนรู้เป็นอย่างยิ่ง กระบวนการเรียนรู้ที่แท้จริงของนักเรียนไม่ได้เกิดจากการบอกเล่าของครู หรือผู้เรียนเพียงแต่จดจำแนวคิดต่างๆ ที่มีผู้บอกให้เท่านั้น กระบวนการเรียนที่ผู้เรียนจะต้องสืบค้น เสาะหา สืบหา ตรวจสอบ และค้นคว้าด้วยวิธีการต่างๆ จะทำให้ผู้เรียนเกิดความเข้าใจและเกิดการรับรู้ความรู้นั้นอย่างมีความหมาย จึงจะสามารถสร้างเป็นองค์ความรู้ของผู้เรียนเอง และเก็บไว้ในสมองได้อย่างยาวนาน สามารถนำมาใช้ได้เมื่อมีสถานการณ์ใดๆ มาเผชิญหน้า ดังนั้นการที่ผู้เรียนจะสร้างองค์ความรู้ได้จึงต้องผ่านกระบวนการเรียนรู้ที่หลากหลาย โดยเฉพาะอย่างยิ่งกระบวนการสืบเสาะหาความรู้ (inquiry process)

Teachers should be aware that the learner takes his or her own responsibility in learning. What learners already know influences their learning. Thus, students' experience is an important factor for the learning process, which does not occur by remembering teachers' telling. However, learning occurs through the learning process that learners have to investigate through various methods in order to construct new knowledge and keep in a long-term memory, and be able to face and solve other problems. Learners can construct knowledge through the investigation process called the inquiry process. (Standards, p. 219)

I found evidence that all professional developers displayed a didactic orientation instead of inquiry, guided-inquiry, or other orientations that could serve the request of the Standards. The professional developers still believed that science knowledge is facts, which could be learned by reading or telling from experts. Thus, many professional developers still served their role in telling knowledge to teachers at the end of activities. In addition, the PD implementation of the professional developers revealed that they used activity in the PD as a tool in developing teachers' laboratory skills and also a tool for discovery or verification of the existing knowledge. Thus, the professional developers provided a set of activities for teachers to investigate rather than challenging them to define problems and design their own investigation.

The professional developers displayed that their understanding about the 5E model of instruction deviated from the Standards. Also, their orientations, which were activity-driven and didactic orientations, led their PD implementation to be different from

the purpose of the Standards. As the Standards explained each phase in the 5E model of instruction, the explanation phase was described as:

ชั้นอธิบายและลงข้อสรุป ผู้เรียนนำข้อมูลจากการสำรวจตรวจสอบมาวิเคราะห์ แปลผลสรุปผล และนำเสนอผลที่ได้ในรูปแบบต่างๆ ซึ่งการค้นพบในขั้นนี้อาจเป็นไปได้หลายทาง เช่น สนับสนุนหรือโต้แย้งสมมติฐานที่ตั้งไว้ หรือไม่เกี่ยวกับประเด็นที่กำหนดไว้ แต่ผลที่ได้สามารถสร้างความรู้และช่วยให้เกิดการเรียนรู้ได้
Explanation and conclusion is for learner to analyze and interpret data or information from the exploration phase. Learner should be able to explain whether or not their analyzed data supports or refutes their hypothesis.
(Standards, p. 220)

However, I found that although the professional developers allowed teachers to perform the activities in the exploration phase, they did not promote teacher learning through the processes stated in the Standards. They rarely encouraged teachers to analyze information that teachers had from observations, conclude or develop explanations based on the data and evidence, or communicate their findings and learning to the peers. The professional developers viewed these processes as wasting their time. Thus, they decided to skip this part, but verbally reminding teachers to do these steps with their students. The professional developers preferred teachers to have hands-on experience from doing as many activities as possible and also preferred to provide much information for teachers. Their teaching behavior during the PD was influenced by the activity-driven and didactic orientations.

Assertion 2: The Professional Developers' Components of PCK for PD were Limited.

These PCK Components were Associated with their Orientations.

Knowledge of teachers' understanding of science. Rather than having solid knowledge supported by research, it is evident that the information on PD participants' knowledge background and understanding of science held by professional developers was mainly from their perspective gained from the previous PD experiences. Based on their

belief that teachers already had good science content knowledge, the professional developers overlooked considering teachers' understanding of science in their PD design. Also, they seemed to have limited knowledge on how teachers best learned science and pedagogy in a sustained and in-depth way, so that they were able to teach science effectively in the classroom.

The standards indicates that learner learn more when new information is structured and related to their prior knowledge and experience, when they are assigned academic tasks at appropriate levels of difficulty, and when they are provided with adequate feedback on their task performance.

ผู้สอนจะต้องตระหนักว่าการเรียนรู้เกิดขึ้นด้วยตัวของผู้เรียนเอง การเรียนรู้เรื่องใหม่จะมีพื้นฐานมาจากความรู้เดิม ฉะนั้นประสบการณ์ของนักเรียนจึงเป็นปัจจัยสำคัญต่อการเรียนรู้เป็นอย่างยิ่ง กระบวนการเรียนรู้ที่แท้จริงของนักเรียนไม่ได้เกิดจากการบอกเล่าของครู
Teachers should be aware that the learner takes his or her own responsibility in learning. What learners already know influences their learning. Thus, students' experience is important factor for the learning process, which does not occur by remembering of teachers' telling.
(Standards, p. 219)

The professional developers' orientations and knowledge were not consistent with the learning philosophy stated in the Standards. The didactic orientation that the professional developers exhibited and their limited knowledge of how people learn and influences of prior knowledge to learning limited them in designing a PD that connected with or challenged prior knowledge of teachers. Also, they paid less attention to providing opportunities for interaction among teachers and challenging teachers' existing ideas.

Knowledge on PD strategy. As indicated earlier, the didactic and activity-driven orientations did not seem to fit with the reformed Standards. During the PD, it was evident that the didactic orientation led the professional developers to play a primary role

as lecturers or discussion leaders when teachers were typically presented with science content, and laboratory activities. In the case of the professional developers who displayed both didactic and pedagogy-driven orientations, it is evident that they did not effectively change their role to accommodate the new instructional approaches that aligned with the Standards. Instead, these professional developers still used a didactic teaching strategy in teaching teachers about the 5E model of instruction. In other words, they modeled *inquiry* teaching methods through a didactic teaching approach. In addition, they paid less attention to helping teachers to recognize the differences between the traditional role and the new role of teachers in the science classroom.

As the Standards explained, the elaboration phase is a phase to encourage learners to use their new knowledge or model in explaining or understanding a new situation.

ขั้นขยายความรู้ เป็นการนำความรู้ที่สร้างขึ้นไปเชื่อมโยงกับความรู้เดิมหรือแนวคิดที่ได้ค้นคว้าเพิ่มเติม หรือนำแบบจำลองหรือข้อสรุปที่ได้ไปใช้อธิบายสถานการณ์หรือเหตุการณ์อื่นๆ เพื่อเกิดความเชื่อมโยงและทำให้เกิดความรู้กว้างขวางขึ้น

Elaboration is a process of learners connecting new knowledge or information to their prior knowledge or ideas. Learner might use new knowledge, models, or conclusions to explain other circumstances in order to make connections and extensions their knowledge. (Standards, p. 220)

The professional developers displayed their understanding that this phase was for the teachers to explain or restate students' explanation into scientific meaning.

ครูจะมาทำในขั้นที่ 4 คือที่เขาพูดมาแล้วอะไรที่ยังเป็นความเข้าใจไม่ถูกต้องครูก็ช่วยแนะนำช่วยบอกว่าอันนี้เป็นอย่างนั้นแล้วครูก็เป็นคนสรุปช่วยสรุปให้อีกทีหนึ่งว่าสิ่งที่เค้าเรียนรู้นี้หลักๆ แล้วมันคืออะไร concept คืออะไร อะไรถูกต้องไม่ถูกต้องสิ่งที่เขาเรียนรู้นั้นเชื่อมโยงกับชีวิตจริงยังไงชีวิตประจำวัน หรือสิ่งที่อยู่รอบตัวเขายังไงบ้าง

Teachers will take responsibility in step 4 by correcting students' explanation from the previous step. Teachers also suggest and help students make correct conclusions about the concept. (Vimon, Interview #1)

ขั้น elaboration นี้ เป็นขั้นที่ครูจะได้ทำงานเสียที่ ขั้นนี้เป็นขั้นที่ครูใช้อธิบาย อะไรที่เด็กเค้าอธิบายมาจากขั้นที่แล้ว ที่เค้าอธิบายไม่ถูก สรุปยังผิด ครูอยากเพิ่มเติมให้ เวลาเด็กเค้าเขียนอธิบายเค้าไม่ได้เขียนแบบที่อาจารย์เขียนเพราะเด็กดัวแต่ตัวเอง ฟันความรู้เค้ายังไม่ถนัด เพราะฉะนั้นอาจารย์ก็ต้องมาอธิบายให้ชัดเจนอีกครั้งหนึ่ง

Elaboration phase is for teachers to explain or rephrase students' explanation to accurate scientific explanations. Students have little knowledge background, so their written explanations may not be correct. (Piti, During PD Implementation)

Thus, the professional developers modeled this phase of the 5E model of instruction by directing teachers to the correct scientific knowledge, not to solving new problems as discussed in the Standards.

The 5E model of instruction also includes the evaluation phase. The professional developers paid less focus on this phase either by developing understanding about assessment and evaluation techniques for teachers or implementing the assessment in order to assess teacher learning. The type of questions used by the professional developers during the PD teaching revealed two possibilities, including (1) limitation of knowledge of questioning or (2) an orientation that framed ways to formulate questions that were less inquiry-oriented.

It is evident that the professional developers tended to view hands-on activity and science content instruction as two separate activities. Rather than teaching content through hands-on activity using the inquiry process as stated in the Standards, the professional developers supplemented the hands-on activities with more didactic or activity-based lessons.

ที่แสดงให้ดูจบไปนี้เป็นเรื่องของกระบวนการสืบเสาะหาความรู้ จบไปแล้วเรื่องกระบวนการจัดการเรียนการสอน ต่อไปเป็นเรื่องเกี่ยวกับหัวข้อที่ต้องแนะนำ อธิบาย หรือให้ความรู้โดยตรง เช่นเรื่องความถี่

I just finished modeling the inquiry methods and that was an example of teaching and learning process. Now I am going to talk and explain to you about the topics that are needed to give knowledge directly. (Piti, During the PD Implementation)

เราไม่ได้ไปลงในเนื้อหามากนักเราแนะนำในเชิงของกิจกรรม ถ้าหากไปลงเนื้อหาอาจจะมีไม่เข้าใจ อย่างบางเรื่องเวลาไม่มีเราอาจจะไม่มีเวลาถามหรือเปล่าไม่แน่ใจ หรือเขาอาจจะไม่กล้าถามเห็นเรารีบจดมุ่งหมายของเราคือพยายามแนะนำกิจกรรมให้กับครู เพื่อที่ให้ครูเอาไปใช้สอน พยายามให้กิจกรรมไปเยอะ ๆ อย่างไฟฟ้าสถิตก็มีหลาย ๆ กิจกรรม พยายาม

แนะนำแนวทางที่นำเสนอยังงใจให้เด็กเข้าใจได้ง่าย ถ้าเกิดมีตรงไหนที่ครูเข้าใจผิดก็จะแก้ไขให้ครูไปขยายต่อ

I do not go into too many details about the content because I want to introduce the activity. If I talk about the content, there might be some teachers who don't understand it. My goal is to give many activities to teachers and encourage them to use these activities with their students. For example, there are many activities about electrostatic concepts that I prepared for them. I try to suggest to them how to use the activity with students in an easy way. If teachers have a misconception, I will help them to correct it. (Vimon, Interview #2)

ที่ไม่ให้ความรู้ส่วนใหญ่ในเอกสารของเรามีเนื้อหาอยู่แล้วเพราะฉะนั้นคิดว่าครูเขาจะไปอ่านเองได้ เราอยากจะเป็นเทคนิคปฏิบัติมากกว่า เพราะเข้าใจว่า ครูกลุ่มนี้ถ้าสอนถ้าเปิดตำราสอนโดยที่ไม่เข้าใจหรือความซำบซึ้งในการทำกิจกรรม

Teachers can read for gaining content knowledge. I want to improve their techniques rather than the content because I'm sure that these teachers follow the activity directions without understanding and appreciation of the activities. (Sommit, Interview #2)

Also, some professional developers exhibited a perceived need to retain control of the learning process in order to ensure teachers were successful in performing activities. For example, Somsri liked to have every teacher move through each activity at the same pace, suggesting that when the teachers did not perform the same activity at the same time, she felt she was losing control of the PD session.

มีอาจารย์บางคนเขาเคยสอนแล้ว เคยสอนในกิจกรรมของเราด้วยซ้ำ แต่พอมาทำ รู้สึกว่าเขาก็ดูสนใจ แต่ว่าเขาทำล่วงหน้าไป ทำล่วงหน้าในสิ่งที่เรายังไม่ได้พูดถึง มันทำให้ความสนใจของกลุ่มมันไม่เป็นไปตามลำดับ บางช่วงต้องดูครูเขาว่าให้เก็บไว้ก่อน อย่าเพิ่งทำ เพราะครูบางคนเคยสอนตอนช่วงชั้นสอง แก่ก็รู้แล้วกิจกรรมนี่อะไร มันทำให้กลุ่มอื่นมาสนใจเขา ถ้าเป็นเด็กก็หันมาตรงนี้สิมันสนุก แทนที่จะได้มาพูดเป็นลำดับขั้นตอนไปเรื่อย ๆ นี่ก็เป็นสิ่งที่ไม่ควรเกิดขึ้น

Some teachers used to the activities before they came to the PD. So they did the activities ahead of other teachers, which I think it was very disorderly and uncontrolled. I had to tell them to wait for other teachers because the teachers from other groups were interested in the activities they did instead of paying attention to their own work or my explanations. This should not happen. (Somsri, Interview #2)

In addition, the professional developers rarely provided opportunities for teachers to engage with their peers in focusing on classroom teaching practice and how to make practice effective.

Metaphors for PD could have a strong impact on what professional developers taught during their PD implementation. There were obvious connections between professional developers' images of PD and their teaching behavior. For example, one professional developer had a magician metaphor, which led to the selection of activities that looked miracles, fun, and exciting to teachers. Or, one professional developer held a metaphor of the warehouse and cow ruminant, which meant teachers could not develop knowledge immediately at the PD, but they needed times to recall the activities, explanations of professional developers and then read the PD handbook for content knowledge in order to construct new knowledge. This metaphor led the professional developer provided much information to teachers with little attention to helping teachers to increase knowledge and make connections of PD experience to classroom teaching.

Knowledge on PD curriculum. There is little evidence revealing how much and to what degree the professional developers understood the PD curriculum. However, the data reveal that the professional developers believed that the PD handbook that they provided for teachers contained enough information, such as an activity and its directions, content knowledge for students and teachers, and student worksheets, necessary for teaching. Thus, the PD teachers could review the PD handbook whenever they needed to find information or refresh their existing knowledge. In addition, the professional developers ensured that the PD curriculum was designed to serve the Standards' requirement for content aligned with primary grade levels.

Knowledge on assessment of scientific literacy. Rather than relying on summative assessment only, the reformed Standards recommend teachers use formative and authentic assessment strategies as alternative ways in assessing student learning.

การวัดและประเมินผลมีความสำคัญเป็นอย่างยิ่งต่อกระบวนการเรียนการสอน วิธีการวัดและประเมินผลที่สามารถสะท้อนผลการเรียนรู้อย่างแท้จริงของผู้เรียนและครอบคลุมกระบวนการเรียนรู้ และผลการเรียนรู้เพื่อวินิจฉัยความรู้ความสามารถ ทักษะและกระบวนการ เจตคติ คุณธรรม จริยธรรม และค่านิยมของผู้เรียน และเพื่อซ่อมเสริมผู้เรียนให้พัฒนาความรู้ความสามารถและทักษะได้เต็มตามศักยภาพเพื่อใช้เป็นข้อมูลป้อนกลับให้แก่ตัวผู้เรียนเองว่าบรรลุตามมาตรฐานการเรียนรู้เพียงใดเพื่อใช้ข้อมูลในการสรุปผลการเรียนรู้และเปรียบเทียบถึงระดับพัฒนาการของการเรียนรู้ จึงต้องวัดและประเมินผลจากสภาพจริง (authentic assessment)

Assessment and evaluation are important to the teaching and learning process. Authentic assessment aims to evaluate students' abilities in 'real-world' contexts. In other words, students learn how to apply their skills to authentic tasks and projects. Authentic assessment does not encourage rote learning and passive test-taking. Instead, it focuses on students' analytical skills; ability to integrate what they learn; creativity; ability to work collaboratively; and written and oral expression skills. (Standards, p. 231)

Although the professional developers indicated that they used authentic assessment to assess teachers during the PD, as recommended by the Standards. However, the professional developers only used asking questions and observing teachers' performance, in the assessment process. As the Standards indicated, the purposes of authentic assessment included:

- (1) การประเมินความสามารถของผู้เรียน เพื่อวินิจฉัยผู้เรียนในส่วนที่ควรส่งเสริมและส่วนที่ควรจะแก้ไขปรับปรุง, (2) เป็นการประเมินที่เปิดโอกาสให้ผู้เรียนได้มีส่วนร่วมประเมินผลงานของทั้งตนเองและของเพื่อนร่วมห้อง, (3) สะท้อนให้เห็นถึงกระบวนการเรียนการสอนและการวางแผนการสอนของผู้สอนว่าสามารถตอบสนองความสามารถ ความสนใจ และความต้องการของผู้เรียนแต่ละบุคคลได้หรือไม่, (4) ประเมินความสามารถของผู้เรียนในการถ่ายโอนการเรียนรู้ไปสู่ชีวิตจริงได้
- (1) assess learner's ability in order to recognize what should be supported and adjusted, (2) get learner involved in the assessment process of themselves and of peers, (3) reflect to teacher whether or not he or she can address the needs of individual learner, and (4) assess learner's ability in making connections knowledge to real-life experience. (Standards, p. 232)

It is evident that the professional developers did not provide opportunities for teachers to get involved in the assessment process in order to reflect on their learning achievement. In addition, it is also evident that the professional developers did not ensure that their PD implementation would help teachers to increase their knowledge and implement this knowledge and experience with students. Furthermore, the professional developers did not spend enough time to help teachers develop understanding of assessment strategies or

make connections for teachers to classroom practice, such as what they could learn by examining student work, thinking, performance, and discourse. Hence, the analysis and interpretation of professional developers' knowledge of assessment of teacher's scientific literacy led me to question how much the professional developers know about authentic assessment, to what degree they thought this assessment could be used in the PD, and what factors, excluding time restrictions, influenced the professional developers to not fully perform authentic assessment.

Assertion 3: The Activity-Driven Orientation and Time Restrictions were the Main Influences the Professional Developers' Design of and Selection of PD Activities.

It was evident that the activity-driven orientation of the professional developers influenced their design and implementation of the PD. Many professional developers provided activities that work (Appleton, 2003)-- that met various goals, introduced the science content and science teaching strategies that were required by the Science Education Standards, were hands-on and fun to do, were manageable in the classrooms, and manageable in the PD. They felt limited by time in designing the PD and selecting activity.

The activities that work were required by the reform science education standards.

The professional developers stated that the PD activities were selected from the IPST Curriculum, which was developed under the National Science Education Standards framework. Consequently, the PD activities introduced the scientific concepts the students needed to acquire by the end of each grade level. For the PD, the professional developers indicated that the teachers needed to understand the mission and requirements of the reform Science Education Standards. The Standards requested the teachers teach

science as inquiry and get the students more involved in science. The professional developers were anxious that the teachers understood and were able to do the science activities that were required by the Standards. The professional developers believed that the teachers, as well as the students, would understand some easy science concepts if they got involved in the hands-on activities. Thus, it was necessary for the PD to provide opportunities for the teachers to do those activities before they implemented them in their classrooms. The professional developers also mentioned that if the teachers used the IPST Curriculum and PD activities in their science instruction, they would not have any anxiety that they would not meet the requirements stipulated in the Standards.

หลักสูตรที่เราเสนอให้เขาเป็นหลักสูตรตาม พรบ. ใหม่ที่โรงเรียนหรือครูทุกคนจะต้องสอน กิจกรรมลักษณะนี้ เพื่อให้ตรงตามมาตรฐาน ลักษณะของกิจกรรมอาจจะแตกต่างก็แล้วแต่ เพราะว่าตัวอย่างที่เราเสนอให้มันเป็นเพียงตัวอย่างเพื่อให้ได้ concept ตามมาตรฐานก็เท่านั้นเอง หลักสูตรนี้ก็คงเดิม หลัก ๆ ใหญ่ ๆ เนื้อหาอะไรก็คงเดิมเราอบรมยังงี้ก็หนีไม่พ้นมาตรฐาน เราก็ต้องให้เขารู้มาตรฐานวิทยาศาสตร์ของประมมมีอะไรบ้างแล้วเราก็ให้ความรู้หรือให้ตัวอย่างกิจกรรมในบันทึกกิจกรรม

The curriculum that we introduced to them was aligned with the Standards; these activities were also the kinds that they needed to teach to their students. We wanted them to have the examples of teaching science and the science concepts in the Standards. (Sommit, Interview #2)

หนึ่งให้ครูได้ศึกษาหลักสูตรที่เราจัดไว้ให้ ทีนี้เมื่อศึกษาหลักสูตรก็ต้องรู้ว่าในหลักสูตรมีกิจกรรมอะไรบ้าง เท่ากับให้ครูได้มาฝึกให้แม่นยำขึ้นก่อนที่จะนำไปสอนเด็กถ้าเขาได้ฝึกและเราได้ชี้แนะในสิ่งที่เค้าควรจะเน้นกับเด็ก เค้าก็จะเกิดความมั่นใจขึ้นนั่นคือประเด็นหลักว่า ได้มาฝึกด้วยตัวของตัวเอง ผิดถูกยังงี้เขาจะได้สำรวจตัวของเขาดูว่าที่ผ่านมาเขาทำยังงี้กับเด็ก เราเพิ่มเติมให้เขา เขาจะได้นำไปเพิ่มกับเด็กหรือไปชี้แนะกับเด็กต่อนั่นคือประเด็นที่หนึ่ง

We wanted the teachers to know what was in the Standards. We also wanted them to know the activities in the curriculum. Some teachers may have used these activities with their students before they came to the PD. But, it would be a great opportunities for them to reconfirm whether or not they did it right in the classroom. We also explained more to them so they could do the same thing with their students as well. (Somsri, Interview #2)

The reformed Science Education Standards also required the teachers to teach science using the 5E model of instruction. This requirement also guided the professional

developers to select activities in which they were able to model the science instruction using the 5E framework. For example, the requirement in using the 5E model of instruction guided Piti to select PD activities that fit the 5E model of instruction. As Piti indicated, “The activities that the teachers need to do in the PD must be the activities that lead them to understand the inquiry process” (Piti, Interview #2).

การใช้กระบวนการ Inquiry ในการอบรมเอาอันแรกก่อนเพราะ สสวท. สนับสนุนให้ใช้กระบวนการนี้ในการจัดการเรียนรู้วิทยาศาสตร์ นั่นคือเรามีหน้าที่ที่จะต้องเผยแพร่ออกไป โดยทำให้ดู เราพยายามทำให้ดูโดยที่ไม่ได้บอกเหมือนการบรรยายว่า inquiry 5E ต้องทำอะไรบ้าง 1, 2, 3, 4, 5 อันนี้คือยุทธศาสตร์ที่ใช้ ส่วนการให้องค์ความรู้อันนี้ก็เป็นสิ่งที่เราจะต้องให้ basic concept แก่ครู เราใช้กระบวนการทั้งหมดไม่ได้ เราก็ต้องให้องค์ความรู้โดยตรง การให้องค์ความรู้นั้นก็ต้องสอน วิธีทำการทดลองโดยใช้การทดลองเหมือนในห้องเรียนจริงให้เขาลองทำเป็นกิจกรรมการทดลองที่เราได้เสนอแนะไว้ในหนังสือเรียนให้เขาลองทำเพื่อจะได้นำไปใช้เพราะบางคนเขาก็ไม่เคยใช้หนังสือ สสวท. เขายังไม่คุ้นเคยกับการทดลองเหล่านี้ เขาจะได้เอาไปใช้

The IPST Curriculum requires the teachers to teach science using the inquiry process. So, it was our job to help the teachers understand this teaching technique. We tried not to tell them directly what the 5E was, but we modeled it to them by using this technique. For some of the basic concepts, we needed to inform them of the concepts because we could not use the 5E with all the concepts. We need to teach them. For the activities, we had the teachers do the activities as if they were students. Some teachers never used the IPST Curriculum before; so when they came to the PD, they would not be familiar with it. (Piti, Interview #2)

Vimon and Somsri expressed concern that it was necessary that the PD activities were exactly the same activities as the students. In addition, Somsri and Piti indicated that the teaching strategy used in the PD should be the same as the teaching strategy that they needed the teachers to adopt in the classrooms.

The professional developers believed when the teachers had to teach a particular science concept, they would certainly adopt the activities that they had directly experienced in the PD and had seen with the full array of teaching techniques. However, the teachers might not fully implement the activities that they only had experiences in doing activities and had not seen teaching examples.

คาดหวังว่าในกรณีที่เราแสดงให้เห็น เช่นแสดงให้เห็นว่าเสียงเกิดจากการสั่นของแหล่งกำเนิด ได้รูปแบบเขาคงเอาไปใช้ แต่อันที่เราไม่ได้แสดงให้เห็นรูปแบบคงไม่ค่อยได้ใช้เพราะ เขายังไม่เห็นตัวอย่างว่าเวลาใช้ ใช้อย่างไร

We expect that all things that we fully modeled to them, they would implement it in their classrooms. But, they might not use it if they only had experiences with doing the activities, but did not see the sample of how to teach it. (Piti, Interview #2)

คาดหวังว่าสิ่งที่ครูได้จากเราไปก็น่าจะส่งผลต่อนักเรียน นักเรียนน่าจะสนใจการเรียนการสอนวิทยาศาสตร์มากขึ้น แล้วก็มีความรู้ทางวิทยาศาสตร์หรือ science literacy มากขึ้น หวังว่าครูจะได้กระตุ้นหรือไปเปลี่ยนแนวคิดเด็กที่ไม่ชอบวิทยาศาสตร์หรือที่รักวิทยาศาสตร์ให้รักวิทยาศาสตร์ยิ่งขึ้นหรือให้เขาสนใจ ช่างคิด ช่างสังเกต อะไรให้มากขึ้น เราหวังว่าอย่างนั้น

We expected that the teachers might use the activities with their students, which helps to increase the students' positive attitude to science or develop the students' scientific literacy. We wanted the teachers to help the students to have more scientific skills. (Sommit, Interview #2)

The activities that work were hands-on and fun to do and that teachers could

learn from. All of the professional developers indicated that they selected the PD

activities because they were hands-on activities that would capture the teachers' interests.

The professional developers drew on what had interested the PD teachers from their

previous experiences in PD. The professional developers indicated that if the activities

interested the teachers, they [the teachers] would think those activities would be

interesting to the students as well.

กิจกรรมมันตื่นเต้น สมมติเราเล่นกลทุกคนจะชอบ น่าสนใจ เดี่ยวครูจะเอาไปเล่นบ้างกับเด็ก ครูเหมือนเด็ก ครูก็เหมือนเด็กโชว์หน้าห้องเรียกความสนใจเด็กได้ เขาก็คิดว่าเอาแนวคิดนี้ไปใช้กับเด็ก

The activities were exciting. If we did magic things, the teachers would like them and pay attention to them. Then, they would do these with their students because they knew this would draw the students' interest.

(Vimon, Interview #1)

ครูได้ร่วมมือกัน แบ่งงานกันทำ ถ้าครูได้อภิปรายได้ทำแบบนี้ คิดว่าเด็กก็คงได้ทำลักษณะแบบนี้เหมือนกัน ครูเขาคงจะเห็น point ว่าครูเขาได้อภิปรายหรืออ่าน direction มา อันนี้ผสมอันนี้ มีการวิเคราะห์กันบางกลุ่มมีผสมผิด ผสมคู่คิดมีประเด็นเหมือนกัน

The teachers had opportunities to do the activity, plan, and discuss, which I think the teachers might give the same opportunities to their students as well. When doing these, the teachers might understand why they had to do these processes and when they understand it, they will use it when they return to the schools. (Sommit, Interview #2)

The professional developers also believed that having the teachers do hands-on activities not only helped them to develop conceptual understanding, but also developed laboratory skills. For instance, Somsri indicated that the teachers might not have used the IPST Curriculum before they came to the PD. Other curriculum materials, developed by private companies, usually emphasized content knowledge rather than hands-on activities. Thus, these teachers might not have had many experiences in conducting the activities, and also might not have ideas on how to implement those activities in the classrooms. Somsri mentioned that she selected the activities that allowed the teachers to participate in order to help them understand the content knowledge and improve their laboratory skills.

คนที่สอนแล้วบางทีเขาก็ใช้หนังสือเรา บางทีเขาก็ใช้ของเอกชนซึ่งเขาไม่มีการทดลอง เพราะฉะนั้นเราให้การทดลอง เขาก็จะทำการทดลองแต่ถึงแม้ว่าเขาใช้หนังสือเรา เขาทดลองมาแล้วเขาจะได้สำรวจตัวเองว่าเขาทดลองผ่านมานี้จะมีอะไรเพิ่มเติมให้เขารวมทั้งเทคนิคเออ การสรุปการอภิปรายเออซึ่งเขาจะนำไปใช้ใน การสอนของเขาอีกเขาก็จะได้เพิ่ม

Our curriculum had many hands-on activities, which the teachers would have opportunities to do. Most curriculum from the private publishers usually had no hands-on activities. Whether or not the teachers used our curriculum before, they would have a chance to do the hands-on activities and we would end up by providing them with explanations.

(Somsri, Interview #1)

Vimon was another professional developer who believed that the teachers might develop conceptual understanding of the static electricity concept after they did the activities.

เรื่องเนื้อหาเราไม่ได้อธิบายลึกมากก็แค่อธิบายว่ามันเกิดจากการขัดสี ครูบางคนก็เค้าไม่เข้าใจก็อาจจะเข้าใจ เพราะเราสอนเค้าแบบที่เค้าไปสอนเด็กว่าการขัดสีเนี่ยมันเกิดนะ แต่ว่าเกิดเนี่ยมันเกิดประจุไม่เหมือนกัน บางอันก็ผลึกกัน บางอันก็ดูดกัน คือเราก็ให้เขาทดลอง

We did not explain the concept in depth. But, they might understand it later because we taught them as if they were students. We had them do the activity and taught them the same way that they had to teach the students. (Vimon, Interview #2)

The excerpt above revealed that Vimón selected the hands-on activities because she believed that these activities might help the teachers to develop better understanding of the physics concepts that she taught in the PD. In addition, Vimón stated that when the teachers learned something or enjoyed the activities, they would certainly adopt those activities into their classrooms.

The activities that work drew on equipment that was available in the classroom.

The professional developers indicated that they selected the PD activities based on the materials and equipment that were already available in the classroom. Indeed, the decision of using the activities that needed simple materials occurred before the IPST Curriculum was even developed. Most of the science activities in the IPST Curriculum used science equipment commonly found in schools, rather than more expensive and professional materials. In addition, they also designed the activities that used materials that the teachers could easily find inside or outside of the schools. During the PD sessions, the professional developers tried to introduce the teachers to alternative materials that the teachers could adapt in the science classroom.

Vimón indicated that primary teachers usually ignored teaching science in a way that aligned with the Standards because they did not have the resources and equipment to follow the Standards' suggestions. In addition, it would not be possible for the PD to provide the equipment and material to all schools across the country. Thus, the PD should provide the teachers with alternative ways to modify other materials for doing the science activities. Otherwise, the teachers would not give the students opportunities with hands-on activities. In the selection of PD activities, Vimón chose activities that only needed

common equipment. She also provided alternative ideas about adapting other materials to do the activity.

น่าจะช่วยให้ครูเกิด Idea มากกว่าก็คือจะสอนเรื่องนี้ เดี่ยวนี้เขาใช้อุปกรณ์สื่อตรงนี้ที่เค้ามีย ในห้องไปสอน Idea ที่เขาจะใช้อะไรไปสอนให้เข้าใจง่าย วัสดุที่เราแนะนำเป็นวัสดุที่เป็น ทางเลือกมากกว่าถ้าไม่ใช้ตัวนี้จะใช้อะไรได้บ้าง

We gave them [the teachers] ideas rather than taught them. We introduced the instructional materials that they could use in the classroom. (Vimon, Card Sort Activity)

แต่ตอนกิจกรรมในการทดลองเราคงไม่ให้ครูเขามานั่งทดลองทีละชั้นๆ ถ้าเรียนเรื่องนี้มี กิจกรรมอะไรที่นำไปใช้สอนได้บ้าง แล้วสื่อเราจะหาได้จากไหน เช่นเม็ดยุโรปกับแท่งพลาสติกนี้ราคาก็แสนหาซื้อได้ไหม หาได้ไม่ยากใช้ไหมให้เขาสามารถหาสื่อมาใช้ได้ง่ายๆ ถ้าไม่มี เม็ดยุโรปแท่งไปหลอดกาแฟได้ไหมเศษกระดาษได้ไหม แต่เศษกระดาษมันก็ดูเขยๆ เดิมๆ ถ้ามีสีสันทนอยเม็ดยุโรปสีเด็กก็สนใจมากขึ้น

We won't have the teachers spend times in doing the activities. Instead, we will suggest to them what other activities, besides the activity in the curriculum that they can adopt into the classrooms. We also introduced the alternative materials that they can find in their local area to attract the students' interest. (Vimon, Interview #1)

Piti indicated that the teachers might not use the sound activity because the materials in teaching this unit were expensive. Some of the materials also took much time to prepare. For example, in the activity using the metal string to produce sound, Piti cut the metal rods of a television antenna and used them as metal strings to teach sound. In addition, Piti realized that the schools needed to spend a lot of money to buy tuning forks for each student. Thus, he introduced the teachers to a tuning fork made from a curved steel rod from a window. Piti demonstrated to teachers how to use this tool instead of the more scientific tuning fork.

The activities that work were manageable in the PD. The major aspect of management to which the professional developers referred was the amount and types of activities that were needed to fit within the PD time restriction. In selecting the activities, the professional developers chose activities that introduced the science concepts that were in the Science Education Standards. However, the activities needed to be manageable

within a limited PD duration. For instance, Somsri selected PD activities from the IPST Curriculum. She left out the activities that were too simple, or too time consuming.

Sommit mentioned that he would like to add activities about the acid and base concept if he had a longer PD period. The acid and base concept was included in the Science Education Standards for the primary level. However, it was very superficial at the primary level. Thus, Somsri and Sommit left this activity out. However, Sommit believed that this concept was very important and related to the teachers' and students' everyday life. Thus, if he had more time in the PD, it would be a great opportunity for the teachers to have direct experience with the acid and base activities.

All professional developers indicated that their PD design and implementation decisions were framed by the time constraints. The professional developers indicated that they had to design the PD activities to fit within a 3-hour PD session. In addition, the time restriction was also a major factor of the professional developers in selecting the PD strategies and managing their PD sessions.

บาง Concept ก็ต้องใช้เวลาในการเรียนรู้ ระยะเวลามันจำกัด 3 ชั่วโมง เคมี 3 ชั่วโมง ฟิสิกส์ 3 ชั่วโมง อีกอย่างเราไม่จิงหะที่จะไปตามครูทุกกลุ่มได้ บางครั้งกลุ่มนี้กำลังทำ อันนี้อยู่ อีกกลุ่มไปแล้วผ่านขั้นนั้นไปแล้ว ค่อนข้างที่จะลำบาก แต่เราพยายามที่จะไป พร้อม ๆ กัน

The teachers need to have more time to develop understanding of some concepts. The 3-hour sessions are not enough. In addition, we couldn't closely look at every group because they did not do the same thing at the same pace, although we tried to have them do it. (Sommit, Interview #1)

อย่างเช่นเรื่องการแยกสารนะ ก็ไม่ได้ให้เค้าทำเพราะเวลาไม่มี แต่เราก็อธิบายให้เค้าทุกเรื่อง อันไหนที่เป็นเทคนิคเราก็เน้นให้เค้าแต่เค้าก็ไม่ได้ลงมือทำ แต่ก็คิดว่าถ้าเค้าลงมือจริงๆ มันก็ทำได้เพราะมันไม่มีอะไรยาก แต่มันไม่มีโอกาสป้อนคำถาม เช่น ถ้าเป็นยั้งจี้จะ ทำยังไง มันไม่มีโอกาสได้อภิปราย หรือได้คุยกันเท่าที่ควร

We did not have the teachers do the activity about the separation technique because we don't have time. We only told the teachers, but did not have them to do it. But, I think they can do it anyway even though we did not have them do it in the PD because this was easy. The problem was we did not have enough time to talk, discuss, or question. (Somsri, Interview #2)

รุ่นแรกเวลามันสั้นแสดงอะไรให้เขาเห็นได้ไม่ค่อยชัดเจนเราต้องกระชับขึ้น แต่รุ่นที่ 2 ที่แสดงให้เขาเห็นถึงกระบวนการการเรียนการสอนที่ค่อนข้างจะเต็มรูปหนึ่งเรื่อง นอกจากนั้นก็ทำให้ความรู้ค่อนข้างจะรวดเร็วเพราะเวลามีแค่ประมาณ 1 ชั่วโมง ถึงชั่วโมงนิดๆ

The teachers in the first group did not see everything and we had to make it short because they had a shorter time than the second group, which we could show them all the things that we prepared. The first group only had about an hour for the sound topic. (Piti, Interview #2)

The excerpts above indicate that the professional developers' decision-making about the PD strategies and activities were strongly influenced by time. For example, Sommit indicated that having the teachers do all activities based on their interest solved the problems with the time constraints. If possible, he wanted to allow the teachers to do and finish each activity at the same time and discuss the topic as a group similar to Somsri did in her session. However, the observation of Somsri's teaching led Sommit decide to keep his PD strategies as planned because he noticed that there was not enough time for the teachers to do the activities at the end of the PD curriculum.

The other professional developers exhibited the same concerns over the time constraint of the session. For instance, Vimom believed that the PD session needed to be longer than 3 hours to develop the teachers' knowledge of the discipline. She indicated that providing activities and having the teachers explore the hands-on activity is at that is possible for the time duration provided in the PD.

เราไม่ได้ไปลงในเนื้อหามากนักเราแนะนำในเชิงของกิจกรรม แต่เรื่องของเนื้อหามันสอนในช่วงเวลาแค่นี้มันไม่พออยู่แล้วหรือเขาอาจจะไม่กล้าถามเห็นเรารีบ พยายามแนะนำกิจกรรมให้กับครู เพื่อที่ให้ครูเอาไปใช้สอน เพราะว่าเท่าที่ดูคือพยายามให้กิจกรรมไปเยอะๆ อย่างไฟฟ้าสถิตก็มีหลาย ๆ กิจกรรม

We did not go to the content knowledge but provided ideas and experiences in hands-on activities. We cannot ensure that the teachers understand the concepts within 3 hours. Thus, I tried to introduce many activities to them instead in order to encourage them to implement those activities with their students. (Vimom, Interview #2)

Sommit revealed that if he had more time or more sessions in the PD, he would use different PD strategies. As Sommit indicated, a longer period of PD would allow him

to design his PD session toward problem-based learning or inquiry instruction. It would also allow him to have time to help the teachers develop an understanding of the scientific concepts.

เวลามันไม่พอ พยายามจะเอามาใส่เหมือนกันแต่เวลามันไม่พอ ในเมื่อมันมีเวลาเป็นตัวกำหนดเราก็ต้องเลือกอันไหนที่ หนึ่งครูเขาจะเรียนรู้ง่ายและสองสอนเขาให้เค้าเห็นวิธีการนำเสนอหรือสอนให้เขาสามารถเรียนรู้ได้ถ้าเขาได้ อย่างเวลาเค้าถามเราไม่มีจังหวะให้ก็คือบางอย่างเราไม่สามารถตอบได้ในชั่วโมงนั้นหรือตัวเองไม่มีเวลาที่จะอธิบายได้ในชั่วโมงนั้นต้องทิ้งท้ายว่าให้ไปค้น ถ้ามีจังหวะว่าชั่วโมงหน้าหรือมีเวลามอบหมายไปค้นเป็นชิ้นงาน ครูไปค้นมาหรือให้เด็กไปค้นมาแล้วมาอภิปรายร่วมกัน นี่ก็น่าจะเป็นประเด็นหนึ่งในการเรียนการสอนวิทยาศาสตร์ หรือถ้ามีเวลามากขึ้นก็สอนโดยใช้เทคนิค 5E ได้มีรูปแบบ กับใช้เทคนิค Problem Solving เพื่อให้ครูจะมั่นใจในการที่จะทำ lab มากขึ้น อีกอย่างบาง Concept ครูก็ต้องใช้เวลาในการเรียนรู้ด้วย

We were fixed by time to what activities we would use in the PD. These activities needed to be easy for the teachers to understand. They also needed to learn how to implement the activities in the classrooms and to search for the results and knowledge themselves. We did not have time to answer all of their questions, so we ended up telling them that they needed to search the answers on their own. However, if we had more time, we could have the teachers search [for the answers and information] and come back to share it. We could also model the 5E model of instruction or problem solving strategy. In addition, the teachers also need more time to understand some concepts. (Sommit, Interview #2)

Other aspects of management, including equipment, numbers of PD participants, and the teachers' needs, did not affect the professional developer selection of PD activities. In regard to the number of PD participants, the professional developers indicated that the PD normally had 100 to 200 PD participants. This PD only had 135 PD participants, which they believed, would not be a problem for them to manage. The Kurusapa Business Organization (KBO) provided scientific resources, such as the materials and equipments for the PD session.

In summary, the findings of this study indicate that the professional developers' orientations influenced their PD design and implementation. The professional developers' central goals for PD dominated the PD design and implementation, as demonstrated during the interviews and during the PD sessions. In addition, the PD design and

implementation were also framed by the time restriction. Although the professional developers had many ideas and strategies that they could adopt in the PD, they believed that they were forced to select the strategies that fit the time they were allotted.

Assertion 4: The Professional Developers' PCK for PD Influenced the PD Design and Implementation.

It is evident that limited knowledge of teachers' understanding of science influenced the design of the PD. All of professional developers believed that the PD teachers had good content knowledge in science because most of them had science education background. Also, they believed that the content knowledge in primary science was superficial, which would not lead to any teaching difficulties for the teachers. Furthermore, the professional developers were not concerned about the teachers' alternative conceptions in science. When asked about the teachers' learning difficulties of the particular topics, the professional developers indicated that the primary science topics were simple. The teachers, especially these private school teachers, would not have any problems in understanding the concepts.

เรื่องเสียงเป็นเรื่องที่ส่วนใหญ่ครูมี basic concept อยู่แล้ว ในเรื่องของเนื้อหาเท่าที่ผ่าน มาไม่มีปัญหา มีเฉพาะข้อสงสัยด้านเทคนิคของการใช้อุปกรณ์ต่างๆเช่น เช่น ทำไมเอา แก้วมาลองดูให้สั่นแล้วมันไม่สั่น อันนี้ก็เป็นเรื่องของทักษะในการทดลองที่มันมีเทคนิค เล็กๆน้อยๆ อันนั้นก็คุยกันไป ส่วนใหญ่แล้วเรื่องเนื้อหาไม่มีปัญหา
The teachers usually have basic concept about the sound topics. The understanding of the concepts is not a problem, but the teachers don't know techniques like why there is no sound when they rub the glass that was filled with water. (Piti, Interview #2)

Although Vimom mentioned that the teachers might have some misconceptions about magnetic concepts, she indicated that these misconceptions would not persist after the teachers finished with the PD activities.

ในเมื่อทำการทดลองได้ลองทำด้วยตัวเอง ได้เห็น ได้สัมผัสและเกิดการเรียนรู้ด้วยตัวเอง แล้วเดี๋ยวจะเข้าใจและยอมรับได้ว่าที่เคยเข้าใจมานั้นผิด

They should change the way they think when they are engage in the activities because they will do it and see it. Thus, they should realize that what they know before is wrong. (Vimon, Interview #2)

Vimon, and other professional developers, did not seem to realize that the teachers might have alternative conceptions that were not scientifically accurate before they went through the PD sessions and that those misconceptions often persisted and survived beyond the PD. The unawareness of teachers' understanding of science led the professional developers to disregard the redesign the PD curriculum and strategies that could address the needs of these particular PD participants.

Knowledge of PD strategies also influenced the PD implementation. The understanding of each phase of the 5E model of instruction led professional developers to model this teaching strategy to teachers in ways that deviated from the Standards. In addition, the analysis leaves questions about how well the professional developers understand the PD strategies they used and the complexity of their knowledge structure. These factors influenced the professional developers' implementation. For example, some professional developers only adopted breadth, but not depth of teaching strategies during the PD implementation, which might lead to the development of superficial and disconnected knowledge among teachers.

Their knowledge of assessment had little to no influence on PD design and implementation. The professional developers were neither concerned about the assessment of the teachers' prior knowledge before the PD, nor their learning outcomes at the end of the PD. The professional developers realized that the assessment of teachers' learning was important in order to determine whether or not the teachers' learning really

occurred. They also indicated that the assessment outcomes would allow them to assess if the PD was effective, what made it ineffective, and how to address those defects.

ตรงนี้ยังขาดเรื่อง feed back ที่จะกลับมาว่าเขารู้เรื่องจริงหรือไม่
We need to have some feed back from teachers about whether or not they understand or able to use it. (Piti, Interview #2)

ตอบไม่ได้เพราะเราไม่รู้ว่ามันสำเร็จแค่ไหน ยังไงก็ไม่รู้เพราะเราไม่ได้ติดตาม แล้วก็เราไม่มีเวลาจะมาคุยกับครูเขาว่าพอไหมที่เราให้มันนะ มันไม่มีโอกาสได้คุย
I can't answer it because I don't really know how successful we are. We don't follow teachers to their schools and observe them. We don't have extra time after the session to talk to teachers. (Somsri, Interview #1)

However, the professional developers did not try to integrate assessment within the PD plan. The professional developers explained that although the assessment was important, they did not think the PD had enough time to assess the teachers' learning.

จากปัญหาที่บอกคือเนื้อหามันเยอะ เวลามันไม่ทันถ้าจะทำอย่างนั้นมันต้องเพิ่มเวลาเวลาอบรมต้องมากกว่านั้น เขามีชั่วโมงวัดผล ซึ่งวัดผลต่างๆไปเป็นหลักการวัดผลต่างๆไปไม่ได้วัดผลในเนื้อหาที่เราอบรม ไม่ได้วัด ไม่มีโอกาสได้วัดเลย
The problem is there are too many contents. We don't have time if we do assessment in the PD. IF we want to do it, we have to extend the days. Actually, we have a session for evaluation, but it is not for assessing teachers. We just give general assessment knowledge to teachers. (Somsri, Interview #2)

In addition, they were not certain how to assess the PD teachers when the goal of the PD was to develop the teachers' teaching ability. Another professional developer, Sommit, indicated that it might be difficult to evaluate the teachers immediately at the end of the PD.

รูปแบบไหนที่จะไปประเมินมันลำบากเหมือนกันที่จะให้ครูมาอบรมแล้วประเมินประเมิน ยิ่งงอก่อนเขากลับหรือประเมินหลังจากเขากลับไปแล้วจะเอาอย่างไรให้มันมีความยุติธรรมกับทุกคนเพราะฉะนั้นถ้าเขากลับส่งแบบสอบถามไป เราก็คงไม่รู้ว่าเขาตอบจริงหรือเปล่าเขาให้ใครตอบ
It's difficult to do. We don't know what assessment format we should do. Should we do it right after the PD or after they are back to school. And how will we know if it is fair, how will we know they do the test themselves or have other people to help them. (Sommit, Interview #2)

He believed that the evaluation outcomes might not be accurate because the teachers needed time to absorb and “transform” what they learned. He believed that this transformation needed time to occur. The teachers might use their prior knowledge before the PD to complete the testing rather than the knowledge that they earned from the PD.

Based on these constraints, the professional developers ignored the assessment process in the PD design and implementation. Instead, the professional developers assumed that the teachers might not have any misconceptions. In addition, they might learn something if they did not have any questions at the end of each activity.

ก็เวลาสอนก็จะถามเค้าตลอดว่าเข้าใจหรือไม่ หรือมีปัญหาอะไรมั๊ย ก็ไม่เห็นมีใครถามอะไร แล้วเค้าก็ทำกิจกรรมได้ ก็แสดงว่าเค้าเข้าใจกันดี อันนี้ก็ไม่รู้นะ จริงๆ เค้าอาจมีไม่เข้าใจเหมือนกัน แต่เราไม่มีเวลามาวัดผลอะไร ก็ต้องยกประโยชน์ในจำเลยไป
I always ask for their understanding, but I don't hear any teachers have problems. I think when they see the results of activity, they will understand it. I don't know... I might be wrong. However, I don't have time to assess them, so I give them credit by assuming they understand all.
(Vimon, Interview #2)

Summary

The findings discussed in this chapter reveals that the professional developers displayed multiple orientations. These orientations included activity-driven, didactic, and pedagogy-driven orientations. The individual professional developer could exhibit more than one orientation when they designed and implemented the PD. These orientations within an individual professional could be either consistent or inconsistent when they taught different topics or lessons. In addition, there is evidence that the orientations that were found among the professional developers mostly deviated from the reformed Science Education Standards.

The professional developers seemed to lack PCK for PD, including knowledge of teachers' understanding of science, PD strategies, PD curriculum, and assessment of

teachers' scientific literacy. The limitation of one type of knowledge affected other types, including orientations.

The professional developers' knowledge and orientations influenced their decisions of selecting PD activities and teaching approaches. The professional developers implemented their teaching using the activities that work (Appleton, 2003), including (1) introducing the science content and science teaching strategies that were required by the Science Education Standards, (2) using activities that were hands-on and fun to do, (3) using activities that were manageable in the classrooms, and (4) using activities that were manageable in the PD.

Professional developers' orientations, PCK, and time constraints influenced their design and implementation of the PD.

CHAPTER FIVE: FINDINGS ABOUT ELEMENTARY TEACHERS’ KNOWLEDGE, ORIENTATIONS, AND PRACTICES

I organized this chapter by beginning with a description of classroom implementation, orientations, and PCK of each of the elementary science teachers, Manee, Chujai, Jinda, and Wanna. Then, I present the cross-case analysis and assertions that I developed from the data to address the research questions about the primary science teachers’ knowledge, orientations, and practices in primary science teaching.

The Individual Cases of Professional Development Participants’ Implementation, Orientation, and Pedagogical Content Knowledge for Science Teaching

Similar to the previous chapter, I defined central component of orientations as goals that dominated the primary science teacher participants’ thinking and appeared to drive their instructional decision-making process. These goals were highly visible during classroom instruction, the card sort activity, and interviews. I defined peripheral goals as secondary goals that hardly seemed to influence decision-making. The science teacher participants might have stated something about these goals, but they were not demonstrated during the classroom instruction.

Manee’s Implementation, Orientation, and PCK for Science Teaching

Classroom Implementation

The first day that I observed Manee’s classroom, she was going to teach about the properties of liquid to the 5th grade students. In regard to this lesson, Manee used the IPST Curriculum and activity worksheet that was included in the curriculum. The activity that Manee prepared for the students on that day aimed to develop the students’ understanding that liquid has constant mass and volume, but its shape will change by the

shape of the container. Before the class, Manee prepared needed materials on each table. She drew a data table on the whiteboard in front of the classroom for the students to put their observation data. When the students came to science classroom, they were assigned to sit in groups of six students. Manee reminded the students of previous instruction by telling them that they had learned about the properties of matter in the solid state in a previous week and today they were going to learn another state of matter called the liquid state. Then Manee asked the students to open the activity book and put the date on the top of the activity sheet. Manee asked the students to look at the materials on the table while she introduced each material and its function. At the same time, Manee wrote the name of the materials on the whiteboard. She told the students how she wanted them to do the activities, to observe, and to record the data in the table. Manee strictly followed the activity directions in the teacher-guided book. She asked the students not to start doing the activity when she was explaining to them how to perform the activity, but to carefully listen to her explanations. Although Manee reviewed the activity directions with the students before allowing them to do the activity, she manipulated the students' investigation by telling them to perform the activity step by step following her guidance. Manee believed that the students learn better when they are engaged in hands-on activity and see the results of the activity before hearing her instruction.

เด็กเขาจะได้เห็นของจริง สัมผัสของจริง เขาเกิดความสนใจ และเขาสามารถตอบคำถามเองได้ มันเหมือนกับเห็นผลนะค่ะ บางทีเราให้นักเรียนเรียนแต่ในหนังสือ โดยที่เราไม่มีอะไรให้เขาเลย เขาก็ไม่เห็นของจริง เขาก็นึกภาพไม่ออกว่าผลการทดลองมันต้องเป็นอย่างไรนะ พอเขาทำจริงปุ้ปอย่างตั้งถุงกระดาษ โอเคมันมีแรงกดนะ เขาก็จะตอบของเขาได้ โดยที่เราไม่ต้องมานั่งพูดมาก ไม่ต้องมานั่งเหมือนครูบอกทุกอย่าง เขาเห็นของเขาเอง Students will see and do activity and then they will have interests about the activity. They can answer questions because they have that image and teachers don't have to tell them everything. If we only tell them or have them read from a book, they won't know it because they don't see it themselves. (Manee, Interview #1)

This belief drove Manee's decisions and actions in her classroom. After she clearly explained to the students what she wanted them to observe, she provided opportunities for the students to engage in hands-on activity. Following the instructions about implementing the activity, Manee prepared many containers for each group of students, such as a graduated-cylinder, flask, soft drink bottle, and beaker. In order to find the mass of water, Manee asked students to put a graduated cylinder in a plastic bag and weigh the cylinder with a balancing scale. Then, Manee told the students to pour colored water into a graduated cylinder and put it in a plastic bag to weigh water with a balancing scale. Manee asked students to subtract these two numbers and record on the white board in front of classroom. Manee told students that they had to subtract the weight of graduated cylinder and the plastic bag from the weight of water plus the graduated cylinder plus the plastic bag because they needed to find out the weight of water only.

Manee then organized the students to do the next activity, which aimed to find that the volume of liquid is constant, no matter what shape the liquid takes. Manee had students pour colored water from a beaker into a cylinder until the volume was 25 milliliters (ml). Manee waited until every group finished this process and then asked each group to put the volume of the water on the board. Then, Manee told the students to pour the water from the cylinder into a flask, from the flask to a glass, and from the glass to a beaker. Finally, Manee asked students to pour the water in the beaker back into a cylinder and read the volume of the water. Manee told the students to put the resulting volume on the board. While the students were doing the activity Manee traveled from group to group to observe the students' investigation. She told the students to redo the activity again when the students did not see the expected results. During the activity, Manee continually

reminded the students to use the materials scientifically correctly. For example, Manee warned students to put the graduated cylinder on a table, make their eyes at the same level of water in the cylinder, and then read the number. During the activity, Manee asked students to write their observation data on the board in front of the classroom. When students finished the activity, Manee asked them to open their activity book and look at their observation sheet. Manee asked the students to enter the data from their observation onto the observation sheet. Rather than asking the students why they did not have the same weight of water, Manee directly told the students that “each group might not have the same volume of water because you used different graduated cylinders and they were made from different materials” (Manee, Classroom observation). In regards to the second activity focused on finding the volume of water, Manee asked students whether or not the volume of water changed after students poured the water from a cylinder to several containers and back to the cylinder again.

- Manee: Why did the volume of water of some groups decrease?
Students: Water is left.
Manee: Where is water left?
Students: In the containers.
Manee: Yes, some groups had volume of water less than the beginning because there is some water left in each container.
Manee: Can the volume of water increase?
Students: No.
Manee: If volume of water increases, that means you added some water in the cylinder.
Manee: O.K. Copy what I just said on your worksheet.
(Manee, Classroom Observation)

It was during the time that the students were putting data on the worksheet that they asked Manee what the unit they should use to represent the amount of liquid because they saw the *milliliter (ml)* on the graduated cylinder, but *cubic centimeter (cm³)* on the

activity worksheet. To response to the students' question, Manee had the students change the words 'cubic centimeter' to 'milliliter' without any explanation for the change.

Then Manee demonstrated the next activity to students. This activity aimed to develop students' understanding that the shape of water is changeable. Manee asked students to observe the shape of colored water in a soft drink bottle and then she poured water into a flask. Manee asked students to observe shape of the water in the flask before she poured the water into a beaker. Then, she asked students what shape the water looked like when it was in the soft drink bottle, flask, and beaker. Manee instructed the students to write the property of liquid in terms of its shape on the worksheet. During the conclusion step, Manee told students to write the conclusion following what she told them. At the same time, she wrote the conclusion on the whiteboard for the students to copy onto their observation sheet.

It appeared that Manee rarely provided opportunities for the students to formulate their own explanation using their observation data. Manee's questions did not challenge the students to develop critical thinking, but focused them on telling the facts. Manee ignored the wrong answers of the students many times. She only asked the students who were able to give the right answer to restate their answer for the students in the class.

In the next science class, Manee introduced the properties of gas. She wanted the students to understand that gas has mass, but its volume and shape will change by the container. Manee used similar teaching strategies that she used in teaching the properties of liquid. She started by reminding the students that they had already learned the properties of matter in solid and liquid states. She introduced each material that students had to use in the activity and wrote the names of materials on the board. Manee

overviewed the activity directions and directed the students to perform the activity step-by-step following her guidance. Similar to the activity on properties of liquid, Manee used the IPST Curriculum and observation sheet. She strictly followed the activity instructions. Students followed Manee's directions even though they found that Manee misunderstood the activity directions. For example, in the activity that aims to introduce the concept that the volume of gas is changeable, the activity directions indicated that students had to get air into a syringe, plug the end of syringe, press the stalk of the syringe, and then read volume. Then students had to release the hand that pressed the stalk of the syringe and read the volume again. Instead of having students follow these steps, Manee told the students to unplug the end of syringe and read the volume. The students seemed to be puzzled, but followed what Manee told them to do. Manee got through this activity very quickly even though she realized that the students still did not understand this concept.

After doing all of the activities, Manee asked the students several questions that focused on facts rather than challenging the students to think about what they found out from the activities. Although Manee provided opportunities for the students to discuss their findings with their peers, she only allowed 1-2 minutes for the students to discuss. Manee did not encourage the students to show their ideas. Manee asked the students to copy her words onto their observation sheet. Manee wrote the conclusion on the whiteboard for the students to copy down on their observation sheet.

Another science lesson that I observed Manee teaching was a Sound Lesson. The activities that Manee provided for students included making sound from different materials, such as a brandy glass, a plastic straw, and two tendon strings that were pulled

tight liked guitar strings. According to the brandy glass activity, students were asked to pour 50 ml into a glass and rub the glass to make sound. Manee asked students to observe water in the glass. According to the plastic straw activity, Manee asked students to cut one end of the straw to a “V” shape. At the beginning, Manee asked students to blow the end of the straw that had not been cut. However, students told her that the direction stated to blow at the other end. Manee went back to check the teachers guidebook and found that she misunderstood the activity direction. Then Manee asked the students to blow at the end that had the “V” shape and observe what happened after blowing the straw. Manee provided a new straw to each student and asked the students to cut the new straw shorter than the first one. Manee asked students to compare sounds from the two straws. Manee had only one kit for the tendon string activity. Thus, she took this kit to each group of students and asked them to play on the thick string and thin string. Again, Manee asked students to compare the sound from the two strings. To teach this lesson, Manee still used the same teaching strategies as when she taught the lesson on properties of matter. Manee still directed students to do activities, fill in activity results on the observation sheet, and copy explanations and conclusions from the whiteboard onto their worksheet.

The next day, Manee showed a guitar to students. She played the guitar by making sound from the thinnest string. Manee asked the students how they liked the sound. Then she played the guitar again, but made sound from the thickest string and then she asked students to compare the sounds they had heard. Then, Manee focused students on the concept on pitch.

Manee: We learned yesterday that sound is made by the vibration of ...
Students: Objects.
Manee: Or sources.
Manee: Today I bring a guitar. Does each guitar string have the same size?
Students: No.
Manee: The strings of guitar are similar to the tendon strings that we played yesterday. Do you remember?
Students: Yes.
Manee: If I play the thickest string of guitar, the sound will be ...
Students: Low tone.
Manee: If I play the thinnest string on the guitar, the sound will be ...
Students: High tone.
(Manee, Classroom Observation)

Then, Manee had the students develop their own concept map about sound.

However, Manee continued to direct the students while they developed the concept map. She wrote a format of the concept map on the whiteboard for the students. She asked the students to write the statement “the musical instruments make sound” in the middle of a page. Then she had the students put glue on pictures of musical instruments that they brought to the class. Manee had students draw a line to link between the pictures and the statement above. Then she asked the students to write near the pictures about the action that students had to do with those instruments to make sound. Manee urged the students to color their concept maps. It seemed that Manee did not use the concept map for the benefit of observing how the students scientifically understood the concept of sound. Manee focused on the artistic work rather than the students’ conceptual understanding on this topic. When the students did not make their map colorful, she asked the students whether or not they wanted to redo their map -- otherwise they would not get a good score on their map.

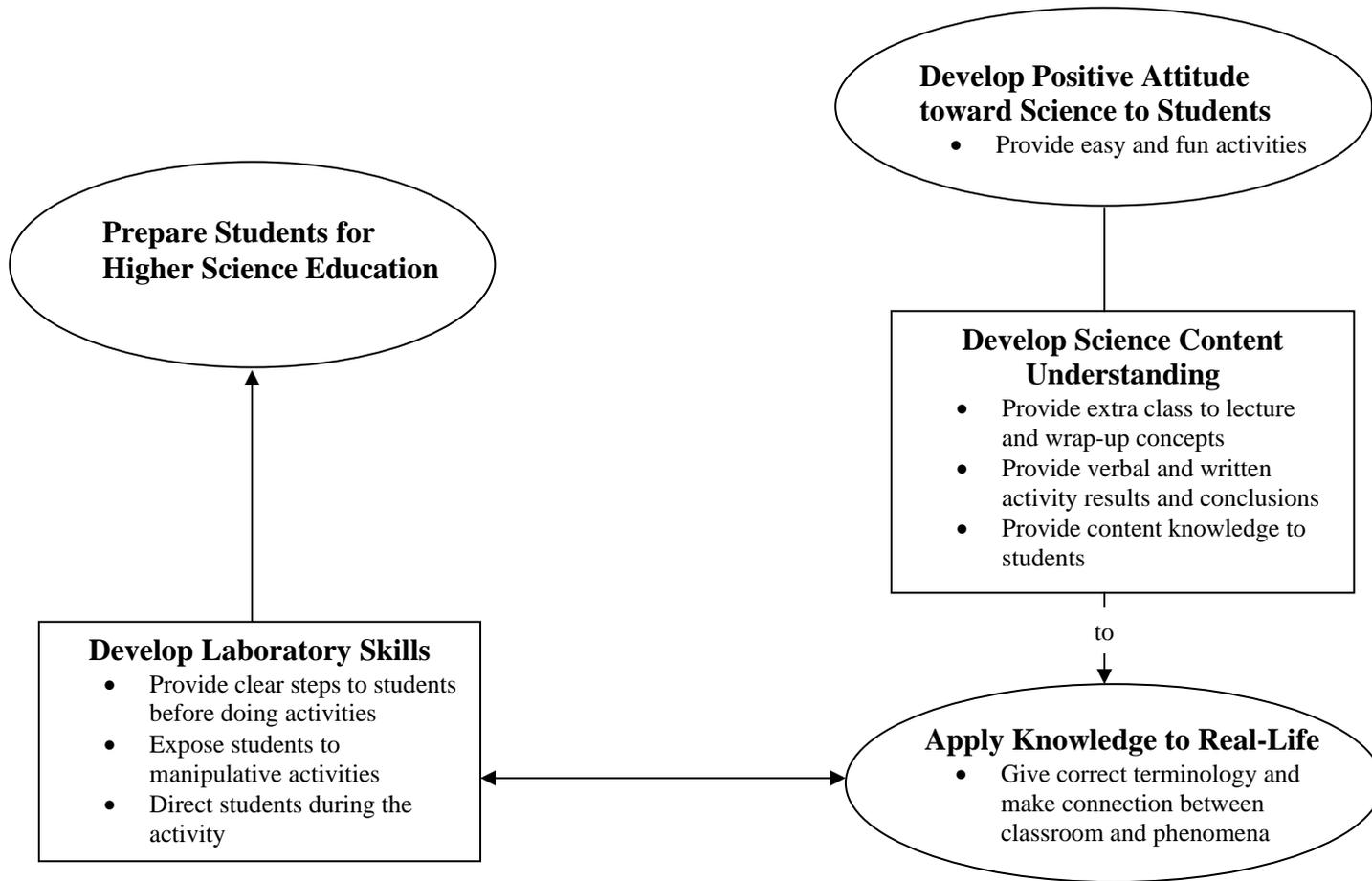
Teaching Orientation

Figure 15 represents my analysis of Manee's orientation. The data from the interviews, card sort activity, and classroom observations with Manee indicated that her orientation to primary science teaching consisted of two central goals and three peripheral goals. Manee's central goals for teaching primary science were to 1) develop students' accurate science content knowledge, and 2) develop students' laboratory skills. Manee's peripheral goals for primary science teaching were to 1) prepare students for higher science education, 2) help the students capably apply science knowledge and process skills to everyday life, and 3) develop students' positive attitudes toward science.

วิทยาศาสตร์มันมีกระบวนการทางวิทยาศาสตร์ มันเริ่มจากการที่เด็กเขาได้สังเกตพบเด็กเขา สังเกตอะไรหลาย ๆ อย่างมันเหมือนกับเขาเริ่มมีปัญหามาถาม อยากรู้ อยากทดลอง ซึ่งความรู้และกระบวนการพวกนี้มันเป็นพื้นฐานที่เขาจะต้องเอาไปใช้ในอนาคต ส่วนมากวิชาวิทยาศาสตร์ มันสิ่งรอบตัวค่ะ ที่เขาน่าจะรู้แล้วก็สามารถเอาไปใช้ในชีวิตประจำวันได้
Science is a subject of process. Students have to learn how to make observations, set a problem, investigate, and develop knowledge. These are fundamental features for students to learn science in the future. Science is about phenomena around them so they should be able to apply knowledge of science to their life. (Manee, Interview #1)

In order to develop students' content knowledge in science, Manee exposed students to the manipulative activities. Students were obliged to follow her directions step-by-step in order to move at the same pace and see the expected results. Manee asked students to repeat the activity again if they did not achieve the anticipated results. At the end of the activity Manee provided results and conclusions for the students because she wanted to ensure that every student understood the same thing. It is evident that this goal influenced her teaching when she mentioned that students should have opportunities to do hands-on activities and after that the teacher could provide them with the correct information or factual knowledge.

Figure 15. Manee's Goals for Primary Science Teaching



□ = central goals; ○ = peripheral goals

เด็กทำการทดลองเสร็จก็มีการทบทวนความรู้ โดยครูมาทบทวนเนื้อหาให้ เขาก็ต้องมีการทบทวนเนื้อหาเหมือนกับซ้ำอีกครั้งหนึ่งอธิบายเขาอีกครั้งหนึ่งให้เขาเข้าใจมากยิ่งขึ้น
After students finish an activity, teacher will give content to them. It is like repeating to them again in order to help them understand the concept.
(Manee, Interview #1)

Manee's other central goal for teaching science was to develop students' laboratory skills. In order to meet this goal, Manee introduced each material before students did the activity. She explained the function of the materials and demonstrated how to use them. During the activity, Manee walked around to each group and warned students to use the scientific materials correctly.

In regards to Manee's peripheral goals, Manee reflected on scenario three (as shown in Table 11). She stated that she selected fun and easy-to-do activities for her students because she wanted them to enjoy learning science. In order to help students apply their knowledge to phenomena, Manee indicated that she used a concept mapping technique. This helped students understand how the musical instruments make sound.

จริง ๆ แล้วเรื่องเสียงเป็นสิ่งที่เขาได้ยินมาตั้งแต่เด็ก แต่เขาไม่รู้ว่าความหมายของเสียงมันคืออะไร เกิดขึ้นได้อย่างไร เขาก็ต้องรู้ อีกอย่างหนึ่งก็คือว่าเด็กโรงเรียนเราเรียนวงโยชกั้น เยอะเขาก็คลุกคลีเรื่องเครื่องดนตรีอยู่แล้ว มันอยู่ในชีวิตประจำวันของเขาอยู่แล้ว เสร็จกิจกรรมนี้ก็อาจให้เค้าทำ concept map เพื่อรู้ว่าเครื่องดนตรีแต่ละชนิดมันทำให้เกิดเสียงได้อย่างไร

Students hear sound since they were born, thus, it's very closed to them. But, they don't know about it yet. In addition, many students join the school band and they have music class. So, it is the phenomenon that they experience everyday. After the activities, I will have them do the concept map so they will know how each musical instrument makes sound.
(Manee, Interview #1)

Table 12 shows Manee's arrangement of and reflection on the orientation scenarios that she chose to represent her views of teaching science.

Table 12

Manee's Arrangement and Interpretation of the Card-Sort Scenarios

Items	Scenarios	Manee's Interpretations
3	You, as a teacher, set up classroom lessons for a unit on heat conduction. Using resource elementary books, you select a variety of fun, and easy-to-do activities. (activity-driven)	"I select activities from many resources, not only from the IPST Curriculum. I will select an activity that is appropriate for students in terms of age and ability. And the activities have to be fun so students will not get bored. Students love to do fun things so if I have them do a hands-on activity, they will really enjoy it." (activity-driven)
13	Your students are intrigued with a Thai flute that a classmate has brought to school. As a group, the students identify questions and ways to explore how the flute works. You help the students organize into investigation teams, and you investigate along with the students. (guided inquiry)	"I agree with this scenario but the Thai flute may not be a good example for teaching this concept. I will use other instruments, such as a guitar because I think students can easily see the guitar strings vibrate." (activity-driven)
11	You, as a teacher, begin a unit on Sound by introducing curriculum, explaining materials, allowing students doing activities, and you explaining the concepts at the end of activities. (didactic)	"I do it sometime. I explain about the materials and directions to students before they do the activity because some students don't understand what they have to do. If the activity is easy, I will manipulate them to the give me the right answer about how the activity should work. But, if the activity is difficult or the result is not clear, I will explain to students prior to the activity about what they have to observe." (didactic)
15	You, as a teacher, have students observe a music instrument and generate questions about how sound is produced. Each group designs and carries out their own experiment to test a hypothesis related to the group's questions. (inquiry)	"We may use other materials, such as a bottle instead of musical instruments. In general, I don't have students design their own experiment. But, I ask them to follow the directions in the activity book." (activity-driven)
10	You, as a teacher, want students to learn the heat conduction. You decide to ask your students to observe and record about the material used for cooking utensil. Then you and students design an activity around the question, "What are the best materials in making cooking utensils. (project-based science)	"If I teach this concept, I will do the same thing. But, our students don't have to design the activity because we have a heat conduction kit. My school bought this kit last year. So, every group will do the experiment with this kit." (activity-driven)
4	When doing laboratory activities, you provide students with clear, easy following, step-by-step directions for the activity procedure. (activity-driven)	"I agree with this scenario because it stated that teachers provide clear steps of the activity to students. I do this too, because if we provide a clear explanation to the students and have them follow the steps when doing the activity, it will make them understand it better." (activity-driven)

In addition to the goal of teaching science in terms of developing students' content knowledge, Manee demonstrated a didactic orientation when she was engaged in the card sort activity. Manee indicated that the teaching strategies in scenario 11 were parallel to her strategies in teaching science. At first, Manee put this scenario in the “can't decide” group because she indicated that she did not directly provide an explanation of the activity results to the students every time. If she noticed that the activity was not too difficult for the students to understand, she would just ask them questions that guided them to the correct answers.

เป็นบางครั้งค่ะ ถ้ากิจกรรมที่ง่ายๆ เราก็ถามเด็กแล้วตะลอมเข้ามาว่าผลการทดลองเป็น
อย่างนั้นะ
If the activity is easy, I will manipulate them to the give me the right
answer about how the activity should work. (Manee, Card Sort Activity)

However, if the activity was too abstract for the students, she had to explain or guide them about where and what to observe before letting the students do the activities.

บางครั้งก็ต้องอธิบายเค้าก่อน ไม่ใช่ให้เค้าทำเลย เพราะบางที่เค้าก็ไม่เข้าใจ บางการ
ทดลองมันยาก เราต้องอธิบายก่อนแล้วค่อยให้นักเรียนสังเกตผลว่าเป็นยังไงเพราะบางที่
การทดลองมันก็ไม่ชัดเจน เราก็ต้องบอกเค้าว่าต้องสังเกตตรงไหน เช่นเรื่องปริมาตรของ
แก๊ส เพราะเด็กบางคนถ้าไม่บอกเค้าก็จะไม่สนใจ เล่นสนุกไปอย่างนั้น แต่พอสังเกต เค้าก็
จะเห็นว่าเป็นจริง
But, if the activity is difficult or the result is not clear, I will explain to
students prior to the activity about what they have to observe. Sometimes
we have to explain to the students first; otherwise they are not able to do it
[the activity]. We have to tell them the results and then let them see it
through the activity. Otherwise, they will just do it for fun and won't get
anything out of it. (Manee, Card Sort Activity)

However, during the observation of her teaching, I found that Manee manipulated students to the answers that she expected to hear. In addition, she copied the answer from the teacher-guided book to the whiteboard for her students to copy onto their worksheet. During the second interview, Manee was asked that why she had to write the information, such as activity results, and conclusion on the whiteboard. Manee explained that:

จริง ๆ ต้องมีการช่วยกันในกลุ่มก่อน เขาช่วยกันแล้วเขาช่วยเราตอบรวมการอภิปราย เราก็ช่วยกันเขียนลงไปในวันทีกิจกรรม เพื่อให้ได้ concept ที่ดีที่สุดและถูกต้อง ถ้าบางทีเราไม่ช่วยกัน เด็กบางคนเขาก็จะคิดเกิน หรือไม่ตรงประเด็นเราก็ต้องตีกรอบให้เขาเข้ามาหน่อย เราก็ต้องอธิบายเพิ่มเติม แล้วก็ค่อย ๆ ให้เขามาให้ตรงคำตอบ ที่มันควรจะเป็นมากที่สุด

Actually they need to work in a group and then discuss as a whole class. Then, we need to tell them what to write on the observation sheet in order to have the correct concept. If we don't do that some students like to think other things that are not right. So, we have to frame them by giving them some information and then leading them to the right answer as much as possible. (Manee, Interview #2)

Thus, Manee put scenario 11 in the “like me” group when she was asked to reconsider the groups and order of the cards during the second card sort activity. She indicated the teaching strategies in this scenario were close to her teaching style. By writing everything on the board, Manee could ensure that every student would have the right answer and factual knowledge. In addition, Manee also explained the reasons for having students engage in the hands-on activities, following the activity directions and progressing through the activity one step at a time. Manee indicated that:

การอธิบายขั้นตอนให้นักเรียนอย่างชัดเจน และให้เค้าทำการทดลองเป็นขั้นเป็นตอนจะทำให้เค้าเข้าใจได้ง่าย

If we provide a clear explanation to the students and have them follow the steps when doing the activity, it will make them understand it better.

(Manee, Card Sort Activity)

Manee's didactic orientation appeared again when she reflected on scenario 2. Manee put the scenario 2 in the “not like me” group very quickly. She indicated that she did not agree with the strategies in this scenario. She thought, in teaching the electricity lesson that the teachers had to instruct the students prior to having the students do the activity. During instruction, she would explain about the circuit and components of simple circuits. Then, she would direct students to make different types of circuits following her instructions.

ไม่เห็นด้วย ต้องเริ่มสอนก่อน ต้องให้เค้ารู้ก่อนจริงๆแล้วเรื่องวงจรไฟฟ้าเราต้องอธิบายเค้าก่อนเพราะว่าอย่างการต่อวงจรไฟฟ้าอย่างง่ายต้องมีอุปกรณ์ 3 ชนิด ถ้าเราไม่บอกเค้าก่อน

เค้าไม่รู้เรื่องเลย เค้าก็ไม่สามารถต่อได้ ต้องสอนเค้าก่อนว่าอย่างง่ายมี 3 ชนิดแล้วให้เค้าลองต่อไปเรื่อยๆ แต่ละแบบ แบบอนุกรม แบบขนาน อาจจะถามเค้าก่อนว่าอุปกรณ์ไฟฟ้ามีอะไรบ้าง แล้วรู้หรือไม่ว่าวงจรไฟฟ้าเค้าต่อกันยังไง

I don't agree with this card. I think we have to begin with giving them instruction about circuits. We need to explain to them that simple circuits consist of three components. Students don't know it before they come to class. So, we need to tell them. Otherwise, they won't be able to make a circuit. We have to have students make each type of circuit under a teacher's guidance, step-by-step. And we can ask them some questions to make sure that they understand about circuits. (Manee, Card Sort Activity)

When asked about having the students share their experiences and knowledge about electricity, Manee stated that the teacher might ask students whether or not they know what the circuit is. Manee also viewed having students express their ideas about this topic in terms of application of knowledge in this concept rather than the main idea of the concept.

ถามเค้าก็ได้ ลองให้เค้าตอบดูว่าอุปกรณ์ไฟฟ้ามีอะไรบ้าง แล้วรู้มั้ยว่าวงจรไฟฟ้าเค้าต่อกันยังไง

Yes, I may ask them whether or not they know what electrical devices they have in their house. Or, do they want to know how the circuit works. (Manee, Card Sort Activity)

The excerpt demonstrates that although Manee provided opportunities for the students to participate in the hands-on activity, she believed it was her responsibility to develop students' learning rather than believing that the students were responsible for their own learning.

Also, Manee indicated that scenario 3 was parallel to her planning when teaching a lesson. Manee explained that she did not design her own curriculum. Rather, she mainly used the IPST Curriculum in her classroom. In addition, Manee also looked for activities from other resources that were fun and developed students' understanding of the desired concept. Manee indicated that she did not have to worry about lacking materials because her school bought all the necessary materials for doing science activities. She usually

used the manipulative activity kits that were designed for a particular activity. Although she put scenario 10 in a group that represented her teaching style, Manee indicated that she did not provide opportunities for the students to design and carry out their own experiments. Rather, she gave the materials to each group of students and assigned them to do the activity following the directions in a book or her guidance.

เด็กไม่ได้ออกแบบการทดลองเอง เพราะเรามีอุปกรณ์ให้ อย่างเรื่องการถ่ายโอนความร้อน เราก็มีชุดถ่ายโอนความร้อนให้เด็กได้ทดลอง เราก็เลยไม่ได้ให้เด็กทำตรงนี้ แต่เราจะหา กิจกรรมอื่นๆ นอกเหนือจากกิจกรรมของ สสวท. มาเสริมให้นักเรียน

The students don't design their own experiment because we have materials for them. For example, to learn about heat conduction, we have the heat conduction kit for each group of students. However, sometimes we find additional activities from other resources for the students. (Manee, Card Sort Activity)

Although scenario 13 represented a guided-inquiry orientation, the way that Manee interpreted this scenario was not close to this orientation, but was representative of a didactic orientation. Based on the observation of her teaching, Manee brought a guitar to demonstrate to students how each string of a guitar makes sound differently. However, it is evident that the strategy she used with students deviated from the strategy stated in scenario 13. Manee did not have students identify questions and ways to explore how the guitar works. Manee used a guitar in order to summarize with students about the pitch concept. According to the dialogue between Manee and her students (see p. 228), it is evident that the questions Manee asked her students focused on factual knowledge rather than conceptual knowledge. Furthermore, although Manee arranged scenario 4 last among those that represented her teaching strategies, it is evident that she frequently used the strategies in scenario 4 more than the strategies stated in many scenarios that she placed before this scenario.

As Manee reflected on scenarios 10 and 15, she said that she did not allow students to design or control their own investigations. Manee preferred to use manipulative activity kits with her students for doing science activities. As Manee reflected on scenario 16, she said that she did not agree in putting materials at the back of classroom and having students explore independently.

อันนี้ไม่เห็นด้วยเลยคะ เพราะมันจะวุ่นวายไปหมด คุณอะไรไม่ได้ เพราะเด็กเค้ายังเล็กเค้าก็จะเล่นอะไรปะปะไป เราจะแจกอุปกรณ์ให้เลย เออวางไว้ที่โต๊ะแล้วก็ให้เค้าทดลองกันที่โต๊ะ

I don't like this one because it will be uncontrolled. Students are too young to control themselves so they will play around and learn nothing. I will put materials on their table and have them do it at their table. (Manee, Card Sort Activity)

This excerpt confirmed that Manee did not display guided-inquiry or inquiry orientations.

In summary, Manee displayed a didactic orientation about primary science teaching. Manee displayed a didactic orientation in terms of believing that science is composed of factual knowledge that can be transferred from the teacher to the student by telling, lecturing, and giving the right answer. Furthermore, she also demonstrated her belief that there is only one right answer for each question. Thus, Manee asked students to repeat the activity when they did not have similar results to the teacher guidebook. She also had an activity-driven orientation in that she believed that the students should have the opportunity to participate in hands-on activities. Based on the observation of her teaching, Manee paid less attention to whether or not the activities helped the students to develop understanding of the concepts that were taught. Although Manee stated that students would learn science when they visualized the results of the activities, it was more likely that the students would memorize the activities rather than understand the concept from the activities. When the students were doing the activity, Manee expected the students to see what she intended and to have correct answers rather than focusing on

students' ideas and thinking. Manee did not demonstrate guided inquiry, inquiry, or project-based orientations although she sorted the scenarios that represented these orientations into piles that would indicate she held those orientations. It was evident that her didactic and activity-driven orientations influenced her interpretation of these scenarios.

PCK for Primary Science Teaching

Knowledge of students' understanding of science. Manee indicated that in order to help students understand science concepts, such as sound and states of matter, she would allow students to do activities to learn some ideas about those concepts. Then, she would ask questions to the students to help them relate the activity results to science concepts. Manee exhibited understanding about the differing ability levels of students with regard to learning. She indicated that some students liked to think over the main point while others chose not to hit the main ideas. Thus, she had to provide guidance and direct them to get close to the right answer as much as possible.

ในการสอนเน้นให้เด็กทำกิจกรรม ทำการทดลอง ถามตอบในห้องโดยการถามแล้วให้นักเรียนตอบหรือว่าตอบคำถามในใบกิจกรรม แต่มันก็มีเด็กบางคนเขาก็จะคิดเกิน หรือไม่ตรงประเด็นเราก็ต้องตีกรอบให้เขาเข้ามาหน่อย คือถ้าเขาเข้าใจ แค่นี้เราก็ต้องอธิบายเพิ่มเติม แล้วก็ค่อย ๆ ให้เขามาให้ตรงคำตอบ ที่มันควรจะเป็นมากที่สุดโดยที่เราไม่พูดก่อน I will teach by having students do activities. I will question them and see their responses. They also have to work on the activity sheet that I give to them. At the end, I will provide the correct answers and knowledge to the students because some students like to think differently than what we expect. So, I have to manipulate them to have the right answer. (Manee, Interview #2)

In the sound lesson, Manee indicated that the frequency concept was the most difficult concept for students to learn. She stated that the students got confused with terminology about this concept.

ความถี่เสียง เหมือนกับเด็กเขาไม่ค่อยเข้าใจว่าความถี่เสียงมันเกิดขึ้นได้ยังไง ความหมายมันคืออะไร แต่ถ้าเสียงสูง เสียงต่ำ เสียงแหลม เสียงทุ้ม เขารู้เพราะเขาเคยได้ยินประจำอยู่

แล้ว แต่ความถี่เสียงมันเป็นเหมือนกับศัพท์ค่อนข้างยาก ถ้าพูดถึงเด็กน่าจะเค้าก็จะค่อนข้างงง แต่ถ้าเด็กคนไหนค่อนข้างพร้อมเขาก็จะได้

Students don't seem to understand what frequency is. They can understand about pitch because they hear it everyday. But, the terminology of frequency is difficult for students to understand. They get confused at the beginning. However, students who are good in science won't have problems with it. (Manee, Interview #1)

Manee indicated that in order to help students understand this concept, she prepared many activities for students including the “ruler activity” that she learned from the PD.

Then, she helped students answer questions on a worksheet and provided an explanation about the concept to the students at the end.

ก็ต้องมีการทดลองค่ะ จำไม่ได้เหมือนกัน เรื่องความถี่เสียงก็มีหลายกิจกรรมที่เคยก็การตีดรัมบรพัดก็ด้วย ในแบบบันทึกกิจกรรมที่ของ สสวท. แล้วก็มีการตอบคำถาม มีแบบทดสอบท้ายหน่วย เขาต้องสามารถตอบคำถามได้ เราก็อธิบายเค้าเพิ่มเติม

I am sure that I have students do activities, but I don't remember what they are. One of them is a ruler activity in IPST Curriculum. After the activity, I have students work on the worksheet and I provide explanations. (Manee, Interview #1)

When asked about the students' difficulties about the concept of states of matter, Manee indicated that most students did not have difficulties understanding about solid, liquid, and gas. However, students might get confused about the state of some matter, such as jelly.

ไม่ยากนะคะ เค้าค่อนข้างที่จะเข้าใจแต่สารบางอย่างเขาจะงงเหมือนเยลลี่ มันกึ่งๆ เขาจะถามว่ามันคืออะไร

The concept on states of matter is not difficult. Students can understand it. However, some objects, such as jelly, cause confusion because it is very difficult to identify. (Manee, Interview #1)

Manee indicated that she helped students to overcome this confusing by giving them the answer. However, she was not sure whether or not her answer was correct.

จริง ๆ แล้วถ้าเยลลี่เราบอกเขาว่ามันเป็นของแข็งนะ ก็ตอบเค้าบอกว่ามันกึ่งของแข็งและของเหลว ก็ไม่รู้เหมือนกันคะว่าจะตอบเค้ายังไง (หัวเราะ) เขาจะเข้าใจกันว่าของแข็งคือของที่แข็งอย่างเดียว ถ้านิ่ม ๆ ไม่ใช่ของแข็ง เขาจะเข้าใจอย่างนี้มาตั้งแต่ต้น เพราะเยลลี่มันไม่แข็งมันนิ่ม มันหนึ่ก หรือเปล่ายังไม่รู้เลย ลองดูซิ ถ้าสมมติว่าเอาถุงมือหลาย ๆ ใบมาซ้อนกันแล้วหนักไหม แสดงว่ามันมีมวลมันมีน้ำหนัก ก็ต้องค่อย ๆ ไปทีละนิดละหน่อย

I tell them directly that it is in solid state. But, I told them that it looks in between solid and liquid. I really don't know actually (laughing). Students will understand that objects that are in solid state will be hard. If it soft, it is not solid. These are their understanding. And then jelly isn't hard, but it's soft. Doesn't it have mass? Students don't know that. So, I have to tell them think about gloves. One pair of gloves might not weight a lot, but many pairs of glove do. So, we have to help them think. (Manee, Interview #1)

The excerpt above reveals that Manee had limited knowledge on states of matter, which linked to her limited use of an analogy to help students' comprehension of this knowledge. In addition, her didactic orientation drove her decision to provide the answer to students.

In addition, it is evident that Manee displayed limited knowledge on learning processes--that prior knowledge of learners influence learning. When reading scenario 1, Manee quickly put this scenario in the "not like me" group. She explained that the students should have directed hands-on experience. Manee did not agree to have the students draw a picture of sugar in water when they could actually do it. When she was asked about using this activity as an engagement activity in order to explore students' thinking, Manee replied that:

- Manee: ไม่เห็นด้วย ควรให้เค้าเห็นของจริงดีกว่า เค้าของจริงมาให้นักเรียนดูเลยดีกว่า เพราะถ้าวาดรูปเค้าก็ไม่ทราบหรอก ถ้าเห็นของจริงน่าจะเข้าใจ
No, I think we should let the students see it for real. They can't understand when drawing, they have to see it. It is not difficult at all to find sugar and water.
- I: ถ้าใช้เป็นกิจกรรมก่อนเข้าสู่บทเรียนเรื่องการละลายเพื่อดูความคิดเค้าล่ะ
How about using this activity prior to the dissolution lesson in order to see the students' thought?
- Manee: ของจริงเลยดีกว่า ทำให้เห็นเลยดีกว่า
I still think we should let them do it, have them observe it for real.

(Manee, Card Sort Activity)

This dialogue reveals that Manee did not demonstrate an awareness of students' prior knowledge, and the importance of knowing students' thinking. Manee paid more

attention to students' performing the activities than what and how they were thinking about the events.

Based on Manee's explanation of students' learning and understanding of science, she believed that hands-on activity might initiate students' ideas, but learning occurs when the teacher transmits correct knowledge to students. When transferring knowledge to students, Manee did not anticipate students' misconceptions on sound or states of matter concepts. Rather, she believed that students would develop correct understanding on those concepts after they listened to her explanation.

Knowledge of science teaching strategies. Based on Manee's reflection of the card sort scenarios, she believed that science teachers should provide opportunities for students to do activities. Teacher's decision on providing an overview of activity directions and anticipating results to students prior or after the activity depended on the level of difficulty of concepts and activities. For example, during the card sort activity, Manee indicated that when teaching electricity to students, she preferred to give knowledge about circuits to students before having them to do the activity.

บางครั้งก็ต้องอธิบายเค้าก่อน ไม่ใช่ให้เค้าทำเลย เพราะบางที่เค้าก็ไม่เข้าใจ บางการทดลองมันยาก เราต้องอธิบายก่อนแล้วค่อยให้นักเรียนสังเกตผลว่าเป็นยังไงเพราะบางที่การทดลองมันก็ไม่ชัดเจน เราก็ต้องบอกเค้าว่าต้องสังเกตตรงไหน
I need to explain activity directions and activity results to students before allowing them to do the activity. The activities about circuits and electricity are difficult and the results sometimes are not clear. So I have to tell my students what will happen and where to observe. (Manee, Card Sort Activity)

Observations of Manee's teaching revealed that she had limited knowledge of ways to represent and knowledge of the strategies to help them comprehend the specific concepts or relationships. As mentioned in the section on classroom implementation, Manee demonstrated misunderstanding about the procedure and the purposes of activities

many times. In addition, she did not demonstrate her appreciation about the selection of activities that could help students to comprehend the difficult concepts, such as frequency.

จำไม่ได้เหมือนกัน เรื่องความถี่เสียงก็มีหลายกิจกรรมที่เคยก็การตีตีไม้บรรทัดก็ด้วย แต่จำไม่ได้ว่ามีกิจกรรมอะไรบ้าง เด็กเค้าก็ได้ทำบ้าง แต่จริงๆ เรายก้อาศัยอธิบายเค้าว่าความถี่มันคืออะไร

I don't remember what activities about the frequency topic that I provided for students last year. But, one of them was a ruler activity that is in IPST Curriculum. In general, I have students to do activities. But, to help them understand the concept, I will give explanations to them. (Manee, Interview #1)

This excerpt reveals that Manee believed that explanation from teachers was the best way to help students understand the concept.

Knowledge of science curriculum. Manee displayed her understanding about the reformed science curriculum. Manee explained that the new curriculum contained more activities than the previous one. The reformed curriculum focused on students having hands-on experience. The hands-on experiences were designed to help students find information and knowledge in order to explain the phenomenon. In regards to the new curriculum, teachers needed to get student involved in learning by doing activity and develop their own explanation without teacher direction.

หลักสูตรนี้เค้าให้เด็กได้เห็นของจริง สัมผัสของจริง เขาเกิดความสนใจ และเขาสามารถตอบคำถามเองได้ มันเหมือนกับเห็นผลนะค่ะ เขาก็จะตอบของเขาได้ โดยที่เราไม่ต้องมานั่งพูดมาก ไม่ต้องมานั่งเหมือนครูบอกทุกอย่าง เขาเห็นของเขาเอง

This curriculum provides opportunities for students to have real experiences from investigations. Students have to be able to develop their own explanation. I see that they can do it because they have direct experience from the activity, seeing the result. So, teachers don't have to tell them everything. (Manee, Interview #2)

Manee also indicated that the activities in this curriculum were clear in terms of process and results. This aspect of the curriculum made it easy for students to follow and understand the lesson. In addition, compared to the previous curriculum where all grades

had to study light and sound, these concepts were clearly separated in this curriculum.

For instance, light was in 4th grade and sound was in 5th grade.

ต่างกันค่ะ ที่สังเกตเห็นแต่ก่อนอย่างเรื่องแสง ป.4 เรียนเรื่องเสียง ป.5 ก็เรียนเรื่องแสง ป.6 ก็เรียนเรื่องแสงมันค่อย ๆ ไปไงคะ แต่ถ้าเป็นหลักสูตรปรับปรุงใหม่ ป.4 เรียนเรื่องแสง จบ ป.5 ป.6 ไม่มีมันเหมือนกันเป็นเรื่อง ๆ การทดลองจะเห็นชัดเจนมากยิ่งขึ้น จะได้ผลทำให้เด็กเขาเข้าใจมากขึ้นมันมีกิจกรรมที่แปลกใหม่ขึ้นมันไม่เหมือนเดิมทำให้เด็กเขาสนใจ
This curriculum is different than the previous one. The previous one, students in 4th-6th grades have learn light, but now it is clearly separated. In addition, this curriculum has more activities than the last curriculum, which make students' more excited. (Manee, Interview #2)

Hence, it reveals that Manee displayed her knowledge of the curriculum in terms of which concept was taught in what grade. She also demonstrated her knowledge of the differences between previous and current science curricula in terms of goals and objectives for students' learning.

Knowledge of assessment of scientific literacy. In order to assess students' understanding of science concepts, Manee used many methods. These included: questioning, testing, concept mapping, students' responses, and students' work.

ใช้หลายวิธีค่ะ ก็มีการถามคำถามหรือตอบคำถามในห้องเรียน ดูความสนใจ ดูว่าเค้าตอบคำถามในใบกิจกรรมได้มั้ย แล้วเราก็มีสอบปฏิบัติด้วยสอบเทคนิคการใช้เครื่องมือวิทยาศาสตร์ แล้วก็มีการสอบท้ายหน่วย สอบกลางภาค สอบปลายภาค บางเรื่องเราก็มีการทำ concept map ด้วย
I use many methods including questioning during class, seeing their work and their attention, testing after finishing each unit, midterm and final testing. Sometime I have students do the concept map. (Manee, Interview #2)

Manee gave the reasons for using many assessment methods that each method gave different meaning. For example, questioning and students' work showed whether students understood particular concept. Testing, such as midterm or final examination, provided big pictures of students' understanding because tests included many concepts. Manee also explained that students had to participate in laboratory testing in order to assess their ability in doing laboratories.

ที่วัดผลเค้าหลายอย่างเพราะเราไม่สามารถใช้วิธีใดวิธีหนึ่งเพียงอย่างเดียวได้ ต้องเลือกใช้หลายๆวิธี บางทีเด็กเค้าทำข้อสอบแบบได้แต่สอบปฏิบัติไม่ได้ การวัดแต่ละอย่างมันให้ผลต่างกัน อย่างสอบย่อยก็เฉพาะเรื่องนั้น แต่ถ้าสอบใหญ่ก็ให้ภาพรวม แต่โดยรวมแล้วมันบอกได้ว่าเค้าเข้าใจมากน้อยแค่ไหน

I use many methods because one method cannot tell everything. Some students can do a good job on exams, but aren't good in lab. Testing after each unit can tell how much they understand this unit when exams can tell the bigger picture. However, a combination of all results shows how much this student knows. (Manee, Interview #2)

Manee exhibited knowledge of assessment in terms of ways that might be employed to assess specific aspects of students' learning. Her assessment methods fit with her central goals for teaching science. In addition, she demonstrated her knowledge about aspects of students' learning that were important to assess when they learned sound.

เด็กต้องรู้ว่าเสียงมันเกิดขึ้นได้อย่างไร ประโยชน์ของเสียง รู้จักตัวกลาง ประโยชน์ วิธีป้องกัน การเกิดเสียงสูงเสียงต่ำ ความถี่เสียง เด็กก็ต้องรู้ ซึ่งก็คงดูจากการถามตอบในห้องเรียนและในใบงาน แล้วก็จะให้เค้าลองทำ concept map

Students have to understand how sound is produced, what its advantages are. Students have to know what medium that sound can move through, safety, pitch, and frequency. I will assess students from their responses to my questions, their work, and concept maps. (Manee, Interview #2)

However, Manee still directed students when they were doing the concept map. In addition, this might be explained by two reasons. First, Manee did not have understanding about this assessment instrument. Thus, Manee seemed to focus on the artistic quality of students' concept maps rather than students' conceptual understanding, and connection between topics. Second, the didactic orientation showed up when she implemented the concept map in the way that she did it with her students.

In summary, Manee displayed moderate understanding about the science curriculum. However, she did not display adequate knowledge on other knowledge components of PCK, including knowledge of students' understanding of science, science teaching strategies, and assessment.

Chujai's Implementation, Orientation, and PCK for Science Teaching

Classroom Implementation

Chujai was teaching a unit about properties of matter. The topic that she taught, when I observed was heat conduction. Chujai utilized the IPST curriculum and observation sheets for this topic. The activity that Chujai used with her students was the activity that she learned from the PD. This activity was to have students touch spoons that were made from different materials, such as stainless steel, plastic, and aluminum. Then, the teacher poured hot water into a bowl and let the students observe - by touching the spoons - when they could feel hotness.

The students were assigned to sit in groups of six students. At the beginning of the class, Chujai asked each group to look at their table and tell her what they saw. Then, Chujai showed each type of spoon and asked students what material it was made from. The students were interested in the materials and made noise while Chujai kept warning them to be quiet and listen to her. Chujai engaged students by asking them to think whether or not they had ever seen these spoons in their kitchen at home. She also asked the students to think about other utensils in the kitchen that become hot when heated. Chujai allowed students to answer her question and then told them that they were going to do an activity about the heat conduction property of materials. Chujai asked the students to pay attention and listen quietly to her overview of the activity directions. Interestingly, the information that Chujai briefed with her students was similar to what she had been told by Somsri during the PD. For example, Chujai told her students to touch each spoon from its end about 1 cm. In addition, Chujai directly told the students when they must start timing rather than encourage students to discuss and design their

own investigation. During the activity, students seemed embarrassed because they did not feel anything by touching the spoons after Chujai poured hot water into a bowl. Instead, they felt hot when they touched the small bowl that contained hot water and spoons. Many students discussed within their group how they were going to record their data because by touching the spoons they only felt warmth rather than the hotness that Chujai insinuated that they would feel. The students then decided to put the number of times that they felt warmth from touching the spoon. When students finished the activity, Chujai asked them about their results. She asked students to consider the materials that the spoons were made from and encouraged them to make conclusions based on the activity. Under Chujai's guidance, students were able to conclude that stainless steel conducts heat in the shortest period of time whereas plastic does not conduct heat. Then, Chujai asked students:

Chujai: Why do different materials conduct heat differently?

Chujai: In terms of conducting heat, how should we use these material based on their property?

Chujai: Should we use the materials that will conduct heat in everyday life? Should we carry things made from these materials with our hands only?

Students: No.

(Chujai, Classroom Observation)

Chujai asked students many questions at a time and she did not provide enough wait time for the students to think and respond to questions. Sometimes Chujai asked and answered her questions by herself, without waiting for students to answer them. In addition, the questions that she posed to students mostly were close-ended or looked for factual information rather than exploring students' thoughts and understandings.

During the explanation step of her instruction, Chujai provided an explanation to students that focused on terminology and application of the heat conduction concept.

Chujai seemed to miss the important aspect and purpose of this activity. Rather than developing an understanding about the heat conduction concept, Chujai's explanation mainly focused on the decision in using materials based on their properties. In addition, when asking questions, Chujai ignored student answers which were not correct or were not what she wanted to hear. Instead, she only picked students' answers which she expected to hear. For example, when she was talking about materials in terms of heat insulation, she asked students:

Chujai: Look at yourself, what is an insulator?

Chujai: Do you think your clothes are insulators?

(Chujai, Classroom Observation)

Without any responses from the students, Chujai explained that cloth has the property of insulation, that it can prevent heat. One student asked Chujai:

Student A: How about black cloth?

Chujai did not have any response to this comment. She neither stopped nor asked Student A to elaborate upon his question and what he was thinking. Instead, Chujai continued her explanation by giving the example that people used a kitchen towel to carry hot cooking utensils. Chujai repeated her question to students again:

Chujai: Do you think cloth conducts heat?

Students: No.

Chujai: In terms of conducting heat, how should we use these materials based on their property?

Without wait time, Chujai jumped to the explanation that:

Chujai: Cloth doesn't have the heat conduction property. Like plastic, cloth is insulation. So, if anyone say plastic conducts heat, it's wrong.

(Chujai, Classroom Observation)

On the second day of teaching this topic, Chujai taught students using typical classroom questioning and lecturing strategies. She reminded students about the activity

they had done on the previous day. She asked them to state again what material in the activity had the ‘best’ and ‘worst’ heat conduction property. Then, Chujai asked students if they were going to eat hot soup, what type of spoon might they use? Most of the students said they would use a plastic spoon. Chujai stopped the class for few seconds and asked students who would have soup with a plastic spoon. Several students raised their hands up while Chujai indicated to students that they could use a plastic spoon in hot soup only when that plastic could tolerate heat. Chujai continued to explain that, in everyday life, people use spoons made from stainless steel with hot soup because they are durable. The students showed that they were getting confused with Chujai’s explanation because it contradicted what they learned from the prior day’s activity. Chujai realized this confusion so she decided to do the activity about heat conduction again.

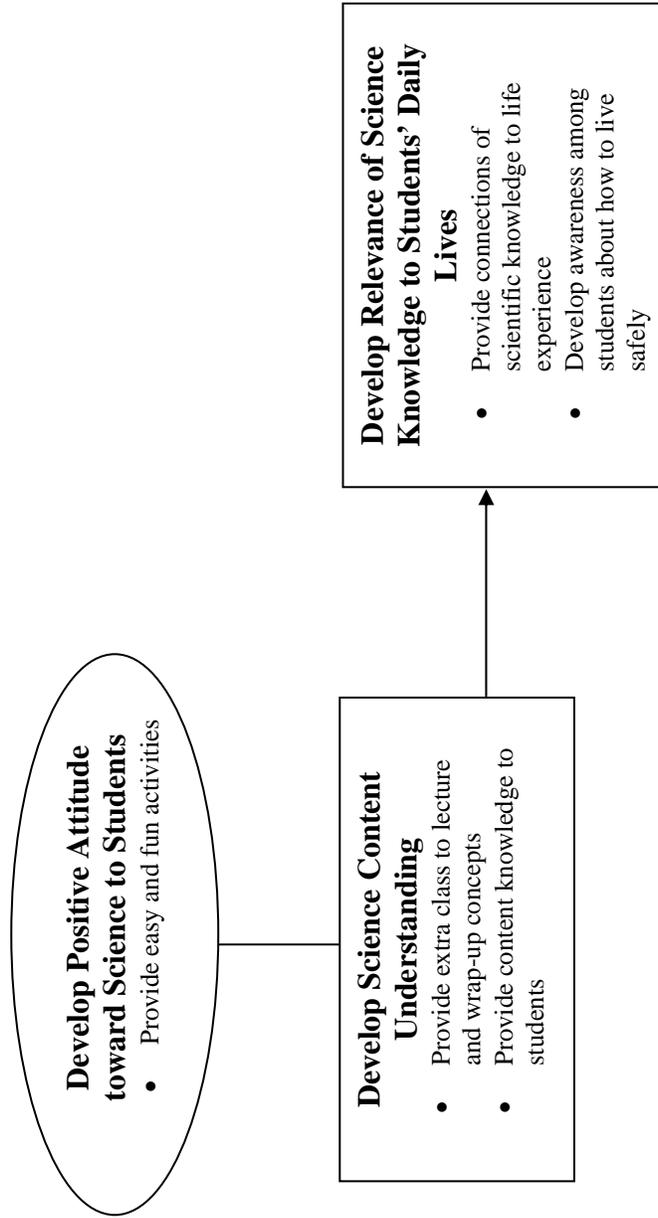
On day three, Chujai demonstrated another activity that she adopted from another curriculum. Chujai dropped wax candles in a row on a steel rod. She clamped the rod tightly then lit the alcohol lamp at the end of the steel rod and asked students to observe what happened to the wax candles. Chujai repeated this activity again, but changed the steel rod to a plastic ruler. Compared to the activity on day one, the students were excited even though they did not have the opportunity to do this activity, but only observed the teacher’s demonstration. After the activity, Chujai used the same questioning strategy she had employed before by asking and answering her own questions. At the end of class, Chujai provided science content knowledge on the heat conduction concept to the students. Chujai provided an oral explanation of the terminology relevant to the concept. She also used an analogy of how one particle transfers heat to other particles. First, she had volunteer students line up. Chujai then pretended she had a hot object on her head,

which made her uncomfortable. She proceeded to pass that object to the student who stood next to her. Then, she asked that student what he would do if he received that hot object from her. The student passed the hot object to his friend next to him. Students seemed to enjoy this analogy. However, Chujai realized that some students still did not understand the notions of “particle” and “transferring.” Thus, she decided to give up her attempt to help students develop a more clear understanding of this concept. She told students who were interested to come to ask her for clarification after class.

Teaching Orientation

Figure 16 represents my analysis of Chujai’s orientation to science instruction. The interviews, card sort activity, and classroom observation with Chujai all demonstrate that her orientation to teaching the heat conduction concept at the primary level consisted of two central goals which included: 1) developing accurate understanding of science content for students, and 2) connecting classroom knowledge to everyday experiences and developing awareness about phenomena. Chujai’s peripheral goal for teaching this concept is not clear. However, it seems her peripheral goal for teach this concept was for students to develop positive attitudes toward science.

Figure 16. Chujai's Goals for Primary Science Teaching



□ = central goals; ○ = peripheral goals

สิ่งที่อยากให้เขาได้ก็คือประสบการณ์จริงจากความรู้ที่บอกว่าการนำความร้อนนี้มันมีวัตถุหรืออุปกรณ์ใดบ้างที่นำความร้อนได้ อยากให้เขาได้ประสบการณ์จริงว่าอุปกรณ์ชิ้นนี้นั้นนำความร้อนได้จริงอุปกรณ์ชนิดนี้นั้นมันไม่สามารถนำความร้อนได้ก็คือความเห็นจริงของเขาและความเข้าใจของเขา คาดหวังว่าสิ่งที่เขาเรียนไปแล้วจะนำไปใช้ในชีวิตประจำวันเขาได้แล้วก็มีความรู้ที่ถูกต้องโดยไปพูดหรือไปอธิบายให้คนอื่นเขาฟัง พูดได้ อธิบายได้ แต่ต้องมีความเข้าใจที่ถูกต้อง

I want students to learn from real experience. Then, they could explain what materials are heat conductors or insulators. I want students to do this activity because it is close to their life. So, students will know what utensils they can safely touch with their hands. I also expect them to have a correct understanding about the concept of heat conduction. In addition, they should be able to share the knowledge with other people. (Chujai, Interview #1)

Data sources compiled for Chujai reveal that her teaching strategies were inconsistent during her interview, implementation, and card sort reflection. The observation of Chujai's classroom while she was teaching the concept of heat conduction reveals that the strategies she used in teaching this concept were different to what she explained during the card sort activity. During the card sort activity, Chujai stated that she would emphasize students sharing ideas and experiences, and formulating explanations of activity results. However, these opportunities rarely happened during her classroom teaching. Based on the IPST Curriculum, the activity that Chujai provided for students on the first day of teaching was designed for third grade students. The heat conduction activity for the fourth graders would need a particular kit for this concept. However, Chujai's second central goal for teaching this concept drove her decision to select this activity. Chujai explained that she decided to use this activity because she thought it helped students connect their knowledge of heat conduction to everyday experiences. She indicated that students should develop an awareness of phenomena around them using knowledge they learned in the science classroom.

ความสำคัญของเนื้อหาในการทดลองเรื่องนี้เพราะว่าในชีวิตประจำวันของเด็กอย่างสมมุติว่าเขาสามารถจะนำไปประยุกต์ใช้ได้ เขาจะได้รู้ว่าทำไมอุปกรณ์เครื่องใช้ในชีวิตประจำวันสิ่งไหนวัสดุชนิดใดที่เขาควรจะจับหรือเปล่า จับได้หรือเปล่าในขณะที่มันมีความร้อนอยู่ ตรงนี้จะทำให้เขาปลอดภัยจากการอยากกรู้อยากเห็นของเขาด้วย ดังนั้นเรื่องการนำความร้อนนี้

คะก็จะทำให้ทราบว่าสิ่งที่ควรหลีกเลี่ยงในชีวิตประจำวันของเขาน่าจะเป็นวัสดุประเภทใดบ้าง อันนี้ส่วนมากก็จะเกี่ยวกับชีวิตประจำวันของเขาที่ควรเรียนรู้และควรระวังกัน เอาไปใช้ได้นั่นเอง

I will use this activity because after doing the activity students could apply their knowledge to their living experience. Students will know what material they should be aware of when it is heated. (Chujai, Interview #1)

According to the card sort activity, Table 13 shows Chujai’s arrangement of and reflections about scenarios she thought would represent her science teaching. Chujai explained that to teach science a teacher needed to look at a variety of resources and carefully decide what activities would be appropriate for students before teaching a particular topic. She also explained that, prior to the lesson, a teacher had to provide opportunities for students to share their ideas about and experiences with that topic. Teachers should also encourage students to work in groups to develop a hypothesis about the study, let them explore during the activity, and then report their findings.

Table 13

Chujai’s Arrangement and Interpretation of the Card-Sort Scenarios

Items	Scenarios	Chujai’s Interpretations
3	You, as a teacher, set up classroom lessons for a unit on heat conduction. Using resource elementary books, you select a variety of fun, and easy-to-do activities. (activity-driven)	“Books are basic resources that we have to know. The activities for students have to be fun and not too difficult for students to do and understand.” (activity-driven)
5	In an electricity unit, you, as a teacher, give students batteries, bulbs and wires. You encourage the students to find all the possible ways to light the bulb. (discovery)	“It is a good activity. We can use either way between giving the activity devices to students and encouraging them to create the ways to make the bulb light. Or, we can have them follow directions first and then encourage them to do it on their own.” (activity-driven)
2	You, as a teacher, begin a unit of electricity by having students talk about their ideas about electricity. Then you allow students to work with a particular circuit and develop their own explanations. You show the scientists’ ideas about electricity and encourage a class to discuss and compare how their ideas are different to the scientists. (conceptual change)	“To teach any topic, I’ll start from something that is close to students’ lives. I’ll talk to them about their experience to see how much they know about this topic. Then, I’ll provide activities to students and give opportunities for them to explain about the activities. If they can give an explanation, it means they understand this topic. I haven’t used the technique comparing students’ and scientists’ ideas. But, I think it’s interesting.” (activity-driven)

Table 13 (continued)

Items	Scenarios	Chujai's Interpretations
1	You, as a teacher, begin a unit of dissolution by asking students to draw a picture of sugar when putting into water. You facilitate discussion among students. (conceptual change)	"I think drawing a picture is a first step of teaching. If we begin with having students drawing picture, we will see their thoughts about that topic, which I believe students have various ideas about sugar melting in water. It is also an opportunity for the teacher to encourage them to orally share their ideas before doing an activity by asking them what happens to sugar after putting it into water." (conceptual change)
4	When doing laboratory activities, you provide students with clear, easy following, step-by-step directions for the activity procedure. (activity-driven)	"I follow these steps. I will provide clear explanation about the activity directions so they can do it correctly." (activity-driven)
6	You, as a teacher, have students to observe two phenomena, salt in water and ice in water, and generate questions about their changes. Each group designs and carries out their own experiment to test a hypothesis related to the group's questions. (discovery)	"I think these are good strategies that are appropriate in teaching science to primary students. I will encourage students to guess about these phenomena and then have students do an activity in order to test their guesses. I like the idea of having students compare phenomena. It makes student develop their observation skills." (discovery)
11	You, as a teacher, begin a unit on Sound by introducing curriculum, explaining materials, allowing students doing activities, and you explaining the concepts at the end of activities. (didactic)	"We might have volunteer students come in front of the classroom or maybe every student touches their neck while saying something. Then, we discuss how sound is produced. After that, the teacher provides a brief overview of the lesson, gives manipulatives and explains their function to students. During and at the end of the activity, there might be some students who still don't understand the concept so teachers have to provide correct content knowledge about that concept to students in order to help them have accurate understanding." (didactic)
8	As a teacher, you want teachers to learn about how sound is produced. You decide the best way to do this is to demonstrate students with various activities to verify a science concept of vibration produces sound. (academic rigor)	"The best method is to have students touch at their neck and then say a word. I think it is better than bringing a musical instrument to teach this concept. The musical instrument should be used when teaching pitch." (activity-driven)
7	You, as a teacher, encourage the students to place an ice brick on their table. You encourage the students to carefully and accurately record their observations in a journal. (process-driven)	"I agree that students need to have opportunities to do experiments, observe, and collect data." (activity-driven)

Thus, according to the card sort activity, Chujai saw the connection between scenarios 2 and 5. She mentioned that she would use teaching strategies in these two scenarios when she had to teach an electricity lesson. Chujai indicated that when teaching science, she liked to provide opportunities for students to express their ideas. Hence, Chujai saw the strategies in scenario 5 as the engagement in order to encourage students to think how they would light the bulb using their own ways. Chujai also indicated that she might allow students to talk about their ideas about this topic, as stated in the beginning of scenario 2 as her engagement technique. Then, she would have students participate in a hands-on activity under her guidance. Chujai explained that:

ถ้าจะเรียนเรื่องอะไร เราจะเริ่มจากเรื่องใกล้ตัวเค้าก่อน คือใช้วิธีพูดคุยเกี่ยวกับประสบการณ์ของตัวเค้าก่อนว่ามีความรู้เรื่องไฟฟ้ามากน้อยแค่ไหน จากนั้นก็มีกิจกรรมให้นักเรียนได้ต่อวงจรไฟฟ้าและให้เค้าได้อธิบาย ถ้าเค้าอธิบายได้แสดงว่าเค้ามีความเข้าใจ ส่วนการให้เค้าเปรียบเทียบความคิดของเค้ากับนักวิทยาศาสตร์นั้นยังไม่เคยลองทำ แต่คิดว่าน่าสนใจและจะลองทำดู เพื่อจะได้คำตอบที่หลากหลาย

At the beginning of each lesson, I will start by talking to students about their experience that relates to the topics that they are going to study. This discussion will allow me to know how much knowledge on electricity the students have. Then, I will allow them to perform activity and develop an explanation from doing the activity. If they are able to explain what they have, then it means they learned something. But, I haven't ever tried to have students compare their ideas with those of scientists, which I think is interesting and I will try this strategy in the future. (Chujai, Card Sort Activity)

The excerpt reveals that Chujai believed that if she had to teach this concept, she would allow the students to share their experience and knowledge in order to explore how much the students knew about a concept prior to instruction. Then, she would lead the students in a hands-on activity, provide opportunities for them to share the findings, and give information and content knowledge to the students at the end of the activity.

Unlike other teachers, Chujai put scenario 1 in the “like me” group and stated that she often used this strategy in her classroom. Chujai explained that a teacher would know

what students were thinking from their drawing. She also mentioned that drawing a picture was one technique to encourage students to express their ideas. She believed that students would show a variety of ideas when putting sugar into water.

ให้นักเรียนวาดรูป เป็นการเริ่มต้นการจะเข้าสู่บทเรียน ถ้าเริ่มต้นแบบนี้ เราก็จะได้ความคิด หลากหลายของเค้า เราก็จะได้ถามนักเรียนด้วยว่าน้ำตาลจะเป็นอย่างไรหลังจากนั้น เป็น แรงจูงใจให้เค้าได้แสดงออก ให้เค้าได้พูด อภิปรายกันก่อนทำการทดลอง จินตนาการของ นักเรียนบางคน บางคนอาจบอกว่าน้ำตาลเป็นก้อน เป็นสีเหลี่ยม อยู่ที่ความคิดเค้า
I think drawing a picture is a first step of teaching. If we begin with having students draw a picture, we will see their thoughts about that topic, which I believe students have various ideas about sugar melting in water. It is also an opportunity for the teacher to encourage them to orally share their ideas before doing the activity by asking them what happen to sugar after putting it into water. (Chujai, Card Sort Activity)

However, Chujai did not further explain whether or not students' ideas would influence her teaching. She only indicated that she graded student drawings as artwork, which she might return to students or keep to show in an exhibition.

แต่บางคนก็ทำให้สวยงามแล้วมันก็เป็นผลงานของเค้าด้วย รูปที่วาดเราก็เก็บคะแนน แล้ว คืนเค้าหรือนามาจัดนิทรรศการได้
Some students make their picture very pretty. With the students' picture, I will give them a score and then return it to students. Sometime I will keep it for showing in a school exhibition. (Chujai, Card Sort Activity)

During the card sort activities with Chujai, I observed that when Chujai recognized crucial teaching strategies for teaching science in the scenarios, she would quickly put those scenarios in the "like me" group. When Chujai did not have any experience in teaching the concepts stated in scenarios, she would consider whether or not the strategies were appropriate to teach science. If they were, then she put those scenarios into a group that represented her teaching.

However, I also observed that if Chujai had experience teaching a particular concept stated in the scenario, she would consider it more carefully and show her thoughts in more depth. For example, based on her experience in teaching this concept to

middle school students, when reading scenario 8, Chujai stated that a good way to help students understand that sound is produced by vibration would be to ask students to touch their neck while they were saying something. Chujai indicated that:

การที่จะให้นักเรียนเข้าใจว่าเสียงเกิดจากการสั่นสะเทือน วิธีที่ดีที่สุดคือให้เค้าจับที่คอตัวเองขณะพูดน่าจะดีกว่า ส่วนการนำเครื่องดนตรีมาใช้น่าจะเป็นการสอนเรื่องอื่น เช่นเรื่องระดับเสียง เสียงทุ้ม เสียงแหลม อะไรประมาณนี้มากกว่า
The best method is to have students touch their neck and then say a word. I think it is better than bringing a musical instrument to teach this concept. The musical instrument should be used when teaching pitch. (Chujai, Card Sort Activity)

When reading scenario 13, which represented a guided-inquiry orientation, Chujai mentioned that the students might not get excited with the Thai flute and she never had her students design their own experiment. As she indicated that:

ยังไม่เคยให้นักเรียนได้ออกแบบการทดลอง เพราะส่วนมากการครูจะ set การทดลองเอาไว้ให้แล้ว เด็กเลยไม่ต้องออกแบบเอง
I haven't tried to have students design their own experiment. Generally, I will set an activity and manipulative for them. So, they don't need to design their own. (Chujai, Card Sort Activity)

Chujai insisted that having students touch their neck would be an appropriate activity to teach this concept. She indicated that rather than having them explore the Thai flute-- which she was not sure whether or not her students would be interested in--she might ask students to touch their neck in order to engage them and encourage them to think how sound is produced. Then, she would encourage students with a hands-on activity that was in the curriculum. At the end of activity, she would explain the sound concept to the students again in order to ensure that every student understood this content knowledge.

เราอาจให้ตัวแทนนักเรียนออกมาหน้าห้อง หรือแต่ละคนเปล่งเสียงออกมา แล้วมาคุยกันว่าเสียงน่าจะเกิดขึ้นได้อย่างไร แล้วถึงค่อยแนะนำบทเรียนที่เราจะเรียนเรื่องนี้เนะ เนื้อหาบทเรียนเป็นอย่างไร แล้วแนะนำวัสดุอุปกรณ์ที่จะใช้ทดลอง นักเรียนบางคนขณะทำการทดลองอาจจะยังไม่ทราบแน่ชัดว่าที่ทำการทดลองไปมันผิดหรือถูกอย่างไร ครูก็น่าจะมีการอธิบายเนื้อหาให้นักเรียนทราบเป็นการสรุปอีกทีนึง
We might have volunteer students come in front of the classroom or maybe every student touch their neck while saying something. Then, we discuss how sound is produced. After that the teacher provides a brief

overview of the lesson, gives manipulatives, and explains their function to students. During and at the end of the activity, there might be some students who still don't understand the concept, so the teacher has to provide the correct content knowledge about that concept to students in order to help them have accurate understanding. (Chujai, Card Sort Activity)

The excerpt above reveals that when reading scenarios about sound concepts, Chujai would refer back to her past experience in teaching this concept. She demonstrated that strategies in her prior teaching about sound had consisted of doing a hands-on activity, questioning and discussing, and providing a teacher-generated explanation. Her reflections on scenario 13 were closer to a didactic orientation rather than a guided-inquiry orientation to science teaching.

In addition to the scenario 13, there were many scenarios that Chujai did not select as representative of her teaching strategies. However, her reflection on those scenarios demonstrated her didactic orientation. For example, Chujai put scenario 14 in the "not like me" group because she believed that to help students understand about circuits and electricity, the teacher had to provide a clear explanation to students about the device and its function. She stated that students might not know about circuits and how to make a simple circuit. So, the teacher needed to provide the fundamental knowledge about simple circuits prior to encouraging them to make each type of circuit by following the teacher's direction. The teaching strategies which Chujai thought would be appropriate to teach circuit and electricity concepts were similar to the strategies used in scenario 11. Chujai stated that a teacher could use teaching strategies as stated in scenario 14 only when they were sure that students already knew all of the necessary information.

ครูควรแจกอุปกรณ์และแนะนำอุปกรณ์ไฟฟ้าแต่ละอย่างให้นักเรียนก่อนว่าอะไรใช้ยังไง มีหน้าที่อย่างไร จากนั้นให้นักเรียนต่อวงจรอย่างง่ายตามเราก่อน แล้วค่อยทำตามวิธีการในข้อนี้

The teacher should begin by giving an explanation about the function of each manipulative to students. Then, students make circuits following the teacher's direction. After that we can have students perform the activity that was stated in the card. (Chujai, Card Sort Activity)

During the card sort, it appeared that Chujai's didactic orientation was not explicit. Based on what she said while sorting the cards, she indicated that her science teaching would be focused on providing opportunities for students to share their experiences and prior knowledge, get involved in hands-on activities, and communicate their findings of the activities. However, the observation of her classroom teaching revealed that the didactic orientation shaped the way she taught science. Chujai did not provide many opportunities for the students to communicate their ideas during her classroom teaching. The discourse that occurred in the classroom was almost a one-way communication in which Chujai asked and answered her own questions. In addition, the questions that Chujai asked her students were close-ended and looked for factual knowledge, not critical thinking. Chujai's implementation of the heat conduction activity with students showed she did not have solid knowledge in the topic that she taught. Chujai's limited content knowledge led her to direct the activity clearly in order to help students understand the concept and see the connection between this concept being taught and their preexisting, familiar life experiences. In addition, Chujai did not appear to be sensitive to the student ideas. It could be said that the limitation of both content knowledge and knowledge of students forced Chujai to ignore *hearing* and *extending* students' thinking, or be able to mediate students' ideas. Instead, she mainly focused on directing students towards what she perceived to be the right information. Finally, it was

clear that Chujai did not understand the purpose or relevance of the activity in terms of how this activity led students to understand the concept.

In summary, Chujai displayed a didactic orientation to science teaching. Although Chujai provided opportunities for students to perform activities, it seemed that the activities did not have any relevance to students' learning of the concept. In the classroom, Chujai still played the major role in presenting information to the students. Her questions aimed to direct students to knowing the facts or the answer that she expected to hear. Although Chujai selected scenarios that represented other orientations, such as conceptual change, academic rigor, process-driven, and guided-inquiry orientations, Chujai interpreted these scenarios through her didactic lens. In addition, it is evident that the didactic orientation directly influenced her classroom teaching.

PCK for Primary Science Teaching

Knowledge of students' understanding of science. Chujai indicated that it was her first time to teach the concept of heat conduction to primary students. Based on her preservice teaching experience with middle school students, Chujai mentioned that students did not have any problems learning this concept. However, she found that students did not understand how to do the laboratory work, for instance, why they had to set a control when doing the activity.

ส่วนมากนี้นักเรียนจะมีความข้องใจว่าทำไมเวลาเราทำการทดลอง เราจะต้องควบคุมสิ่งต่างๆให้เท่าๆกัน อย่างแต่ละกลุ่มบางกลุ่มเพิ่งเทน้ำร้อนบางกลุ่มจับเวลาไม่ถูกต้องอย่างนี้เราก็เลยต้องพยายามทำความเข้าใจก็คือบอกเขาให้เขาเข้าใจว่าสิ่งที่เราต้องควบคุมมันจะทำให้การทดลองของเราถูกต้อง

The majority of students don't understand why we need to set controls when we do experiment. For example, students don't understand that they have to start timing right after I pour hot water into a cup. So, I have to tell them that the control will help them do the experiment correctly. (Chujai, Interview #1)

Chujai indicated that primary students might have different problems with learning this concept. Thus, in order to help these students, she would prepare to answer students' questions. In contrast to teaching middle school students, Chujai implied that in teaching primary levels, teachers need to pay more attention to students' work and provide a clear explanation of activity directions.

ส่วนมากตรงนี้เป็นเด็กที่อยู่ในช่วงมัธยมเหมือนกับเขาจะไม่มีปัญหาในการรับรู้หรือว่าความเข้าใจของเขาตรงนั้น แต่ว่าระดับประถมนี้เราจะต้องเตรียมตัวให้พร้อมกับคำถามที่ผ่านมากับการสอนเด็กประถม เป็นครั้งแรกสำหรับเด็กประถมค่ะ เขาอาจจะมีความเฉื่อยแฉะแต่ขณะที่เคยสอนมัธยมซึ่งส่วนมากเขามีพื้นฐานรู้มาแล้วว่าวัสดุแต่ละชนิดมันต่างกันแล้วก็มี การนำความร้อน นำไฟฟ้าต่างกันเวลาที่เรทำการทดลอง เรา set การทดลองให้เขาทุกอย่างทั้งเวลา ช่วงเวลา จับเวลา วัสดุอุปกรณ์ ต้องจับให้มันเหมือนๆ กัน ก็คือควบคุม control เขาเด็กมัธยมเขาจะเข้าใจ พูดแล้วเสร็จจับจะถามว่าครูทำยังไงนะ อย่างนี้เค้าจะไม่ มี เค้าทำแล้วเขาสนุก

I don't have any problems when teaching middle school students because students are ready to learn. However, I have to be well prepared when I have to teach elementary students in terms of their questions. This will be my first time teaching the concept of heat conduction to the elementary students. They may have a lot of questions about this phenomenon. The middle school students will be well-behaved and know what to do in labs without any guidance from the teacher. But, to teach elementary, I have to direct them to do the activities. It happens many times that they ask me what to do even though I already explained to them. (Chujai, Interview #1)

The excerpt reveals that Chujai believed that primary students needed to be controlled during learning science because they were not able to take responsibility for their learning when compared to middle school students.

Chujai did not anticipate or acknowledge that student might have difficulties with this concept. However, after Chujai taught this concept to her students, she found that students had difficulties understanding the meaning of conduction and that heat occurs through the transferring of heat energy from one particle to other particles.

ในเรื่องความหมายค่ะ การนำความร้อนคือ เพราะเราอยากให้เราว่าความหมายการนำความร้อนจริงๆ แล้วมันคือพอดีในหนังสือมันมีว่าการถ่ายเทพลังงานความร้อนจากอนุภาคหนึ่งถึงอนุภาคหนึ่ง ซึ่งเขาจะค่อนข้างงงเราจะบอกความหมายจริงๆ เขาก็จะงง จนต้องอธิบายกันยาวเหยียด รวมทั้งการแสดงเราก็เลยบอกว่ามันเป็นส่วนของเหล็ก อย่างครูเป็นหนึ่งอนุภาค ก็คือตัวหนึ่งอยู่ในแท่งเหล็กนั้นแล้วก็เพื่อนเธอเป็น 2, 3, 4, 5 รวมกันเยอะๆ แน่นๆ คิดไปว่าทั้งหมดนี้ก็เป็นแท่งเหล็กทั้งหมดเลย แล้วเราก็เลยคิดว่าเดี๋ยวมันจะมีคำถาม

ต่ออีกค่ะ (หัวเราะ) ก็เลยบอกถ้าพวกหนูอยากรู้ความหมายของอนุภาคมันมีความหมาย
ยังใงก็ไปค้นหา สอนเสร็จก็เจียบไปเลยไม่มีคนมาถามอีก

I want elementary students to know the meaning of this word because it appeared in the textbook that heat conduction is a process of transferring heat from one particle to other particles. So, I have to explain and give an analogy to my students. I tell students that particles are small part of iron. For example, I was one particle in the iron rod and there are some other particles lined up together to form the iron rod. I believe that if I go too far with this, there may be a lot of questions. So, I decided to stop and tell students that they can come to talk to me later if they want. But, no one came to see me after that. (Chujai, Interview #2)

To help students overcome this difficulty, Chujai provided an analogy of how particle transfer heat energy to other particles and gave meanings for the terminology. However, Chujai did not spend a long time on the explanation about particles and conduction of heat because she believed that this was too difficult for students to understand.

เพราะว่าถึงเราอธิบายไปเด็กบางคนไม่รู้เรื่องหรือค่ะ ก็จะมีเด็กที่สนใจและเด็กที่ฟังหูไว้หู
เพราะฉะนั้นถ้าคนไหนสนใจก็มา บางทีถ้าเราจะไปเสียเวลาอธิบายให้เค้าเด็กไม่รู้เรื่องก็คือ
ไม่รู้เรื่องอยู่ดี เราพูดไปก็จะเสียเวลาในส่วนที่เราควรจะสอน

I won't spend too much time on helping all students to understand this terminology because it might be beyond the ability level to understand it. It will waste time if I try to make students understand about particles. So, I decided to give up and tell students that they could come to me later if they were interested to know about particles. (Chujai, Interview #2)

According to the excerpt above, it is evident that Chujai learned about what concept or terminology she should give or leave to students. However, this also implies that Chujai believed that when students understood the scientific terminology, it meant they conceptually understood that concept.

Knowledge of science teaching strategies. Similar to other teachers, Chujai indicated that she would begin her science teaching by using questions and discussion in order to engage students with the topic that they were going to study, provide activities, give directions to students, have students do activities, and finally give the correct science knowledge to students.

อันดับแรกก็จะเหมือนการนำเข้าสู่บทเรียนให้เขาบอกว่าในชีวิตประจำวันของเขาวัสดุที่ใช้อยู่แล้วมีอะไรบ้างที่นักเรียนมีความรู้สึกว่ามันร้อนแล้วมันน่าจะนำความร้อนได้ หลังจากนั้นเราก็จะให้เขาลงมือทำการทดลองจากนั้นเราก็มาอธิบายเค้าอีกที

First, I will engage students with the discussion about the materials that they use everyday that they believe might conduct heat. Then, I will let students to do the activity that I prepared for them. When they finish the activity, I will explain to them about the main idea of heat conduction. (Chujai, Interview #1)

เราจะเน้นการทดลอง เน้นเรื่องเนื้อหาให้เด็กเข้าใจ ส่วนเรื่องการปฏิบัติ เด็กก็จะปฏิบัติ เพียงแต่ที่เราอธิบายขั้นตอนการปฏิบัติให้เด็กปฏิบัติเอง เราก็ตรวจสอบดูความถูกต้องความเรียบร้อยของเด็ก

I will emphasize having students to do hands-on activity and develop understanding of the concept. I will provide clear activity directions to students and check for their laboratory skills while they are doing the activity. (Chujai, Interview #2)

Although Chujai indicated during the interview and card sort activity that students would share their experiences about the concept that was being taught, she did not demonstrate knowledge about why having students share is important to the teaching and learning process. Thus she had limited knowledge about teaching strategies. In addition to the didactic orientation that she displayed, a lack of knowledge of strategies led her to teach science in ways that were opposite to what she expected to happen or opposed to what she stated during the card sort activities.

Chujai demonstrated her understanding about using teaching strategies such as doing activities, and answering teachers' questions. These strategies did not only help teachers to understand students' ideas, but would also allow students to check whether or not their understanding about each concept aligned with the correct scientific knowledge.

การถามตอบ การตั้งคำถามไปเหมือนกับว่ามันช่วยจุดประกายให้เขาคิดว่ามันมีสิ่งนี้ๆนะที่เขาคุ้นเคยรู้จักอยู่แล้วบ้าง เขาก็จะตอบออกมา คือเราก็จะสามารถเขียนคำตอบไว้แต่เรายังไม่บอกว่ามันไหนที่มันถูกมันผิดจนกว่าเขาจะได้ทำการทดลองจริงๆในตัวอย่างที่เรายกมา อันนี้เขาก็จะให้เห็นจริงๆเลยเพราะว่าในเด็กบางคนในความคิดเขา เขาอาจจะคิดว่าสิ่งที่เขาตอบไปนั้นมันถูก แต่ว่าคำตอบที่ได้จากการทดลองอาจจะผิดไปก็ได้ เขาก็จะให้เห็นจริงๆว่าสิ่งที่เขาเข้าใจเขาตอบออกไปมันผิดนะ เขาก็จะได้เข้าใจเสียใหม่

Asking questions can initiate students' curiosity of the phenomena that they see everyday. I may have those answers in my notes, but I won't tell them until they do the activity and see its results. Students can check

themselves from my posted question and from doing the activity that their understanding might be wrong. Some students think that their understanding before doing an activity is correct and there might be something wrong with the activity results. So, when I give them the answer they could change this misunderstanding. (Chujai, Interview #1)

Based on the observation of Chujai teaching, it is evident that she did not demonstrate adequate ability in putting her teaching strategies into a sequence that helped students develop understanding of the concept in the ways that she stated in her goals. As illustrated in the section on Chujai's classroom implementation, she seemed to be nervous about the students' questions. Thus, she ignored students' questions and ideas many times. This could be due to her lack of subject matter knowledge and pedagogical knowledge. Furthermore, Chujai did not demonstrate her knowledge of specific strategies that could help students comprehend the concept of heat conduction. Although she used an analogy to represent how one particle transfers heat to other particles, she did not display knowledge about the conceptual strength and weakness of this analogy in relation to students' ability to understand about the transference of heat through particles.

Knowledge of science curriculum. Chujai demonstrated her knowledge of science curriculum and how the new curriculum was different from the previous one. Chujai explained that science was separated from the Life Experience subject, which made students learn science content knowledge more than the previous curriculum. In Chujai's school, she indicated that having science as a separate subject helped to reduce her workload in terms of planning for teaching. For example, instead of teaching all disciplines, including science, social studies, and health education that were integrated in the Life Experience subject, her school assigned teachers to teach a discipline based on their educational background. In regards to this idea, Chujai believed that she would help

students learn science better than teachers who did not have science education background.

สมัยที่รวมกับ สปช. เหมือนกับว่าตอนนั้นอยู่กับคุณครูด้วย ครูที่สอนเขาไม่ได้สอนเฉพาะวิทยาศาสตร์อย่างเดียวนี้ เขาสอนหลายวิชาบางที่ความรู้ที่เราได้ไม่แน่นพอ บางที่คิดว่าความรู้ที่เราได้แต่ก่อนโอเคมีการทดลองจริงตามป่าตามเขาจริง แต่ว่าบางอย่างความรู้นั้นยังเหมือนกับว่าความรู้นั้นยังไม่แน่นมันยังไม่ถูกต้องพอ แต่ว่าในปัจจุบันนี้นะคะหลักสูตรนี้มันเหมือนกับกว้างขึ้นแล้วก็ทันสมัยขึ้นมันเหมาะที่จะใช้ในปัจจุบันแต่สมัยก่อนคุณครูก็จะรู้เฉพาะที่รู้สอนหลายวิชาบางที่ก็สับสนไปบ้างเอาวิชานั้นมาใส่วิชานี้บ้างเพราะว่าแต่ก่อนเรียนโรงเรียนรัฐซึ่งเขาเหมือนกับว่าครูคนหนึ่งสอนหลายวิชา แล้วก็หลักสูตรสมัยนี้มันเกี่ยวกับ internet เกี่ยวกับสื่อใหม่ๆเข้ามาเราก็สามารถที่จะประยุกต์ได้กว้างขึ้นยิ่งรู้มากขึ้นก็สอนมากขึ้นแล้วก็เบลอมากขึ้น ที่นี้จะมีครูประจำวิชาแต่ละคนก็จะรู้ในเนื้อหาของตัวเองมีความรู้แน่นวิชาของตัวเอง เวลาไปสอนก็คือเนื้อหาตรงเป๊ะๆ การทดลองอย่างนี้เด็กจะได้ความรู้มาก ถ้าเปรียบเทียบกับแต่ก่อนที่เราเรียน สปช. เหมือนกับว่าเด็กได้ความรู้ไม่แน่นเพราะว่าบางที่สอนหลายวิชาสอนวิชาของเรายังไม่เท่าไรต้องวิ่งไปสอนอีกวิชาหนึ่ง

This new curriculum is different to the previous one. When science was included in Life Experience subject, teachers had to prepare the lesson plans for three disciplines, which many times teachers might have more solid knowledge in one discipline than the other two disciplines. In the new science curriculum, I only prepare lesson for science. It reduces my workload. In addition, science is my knowledge background so I have more confidence than other teachers who did not graduate in this area in order to help students to develop solid scientific knowledge. (Chujai, Interview #2)

In regards to the excerpt above, Chujai also indicated that the reform curriculum had up-to-date content knowledge, and also integrated technology to teach science, such as through the Internet.

In addition, Chujai mentioned that the new curriculum allowed students to have more opportunities to do hands-on activities than the previous one. However, Chujai did not demonstrate her knowledge about a particular component or activity in the curriculum that helped students to develop important ideas in science.

Knowledge of assessment of scientific literacy. Chujai displayed that in teaching the concept of heat conduction, she would assess students' understanding of the terminology on the conduction of heat. After doing the activity, students should be able to identify what materials had conductor and insulator properties.

เค้าต้องเข้าใจว่าการนำความร้อนนี่คืออะไร มันมีวัตถุหรืออุปกรณ์ใดบ้างที่นำความร้อนได้ อุปกรณ์ชิ้นนี้มันนำความร้อนได้จริงอุปกรณ์ชนิดนี้มันไม่สามารถนำความร้อนได้เพราะมันอยู่ในชีวิตประจำวันของเค้า

Students must understand the meaning of heat conduction. They need to know what materials can conduct heat and what materials cannot. This knowledge is important to them because they face it everyday. (Chujai, Interview #1)

Similar to other teachers, Chujai provided worksheets for students in order to assess their understanding of this concept. Chujai indicated that if student's answers on the worksheet were similar to her answers, it meant the student understood the concept

อันแรกดูจากคำตอบในใบงานที่แตกต่าง คำตอบใบงานไหนที่เหมือนกับคำตอบของเราเด็กกลุ่มนั้นเขาจะเข้าใจ แต่ถ้าเด็กกลุ่มไหนที่เฉไฉไปเรื่อย เพราะเด็กบางคนพอให้ทำการทดลอง พอให้ตอบคำถามเขาคิดเอง เขาไม่ได้คิดจากการทดลอง จากคำถามหรือจากคำอธิบายของครู เขาไม่ใส่ใจบางทีเด็กเป็น ไม่ใช่บางทีแหละ ส่วนมากเลย เพราะว่าคนที่เค้าไม่สนใจเวลาทำการทดลองสนุกสนานไปแต่ไม่ฟังคำอธิบายของเรา คำตอบของเขาก็จะเฉไฉไปเรื่อยไม่ตรงตามเป้าของเรา เราก็จะรู้ว่าคนนี้เป็นยังไง ในบทเรียนนอกจากการทดลองเสร็จจับเรื่องการส่งใบงาน ความตั้งใจในการเรียนด้วย เด็กบางคนก็นั่งเฉยพอเราถามให้ลูกตอบไม่รู้เรื่อง ตอบแบบไม่ใช่จุดประสงค์ที่เราต้องการเราก็จะรู้ว่าเด็กคนนี้ไม่รู้เรื่อง เราก็สอนซ้ำอีกถ้าดูแล้วมีมากกว่า 5 คนสอนซ้ำค่ะ สองคนก็ตามเพราะว่ามันจะไปเสริมสำหรับคนที่รู้อยู่แล้วแต่คนที่ไม่รู้เหมือนกับต้องเริ่มใหม่มันเสียเวลานิดหนึ่งแต่ก็ต้องเสียเวลา

I will look at the students' answer on the worksheet. If their answer is similar to mine, so they understand the concept. Some students like to think on their own. They don't think from the activity or my explanation. These students don't do the activity and listen to me seriously, but just play around. Thus, their answers in the worksheet will not be correct. I will also assess students from their intention and participation during class. If I find at least 5 students don't understand the concept I taught, I will re-teach that concept to students although it will waste my time. (Chujai, Interview #2)

The excerpt above reveals that Chujai's orientation, and knowledge of students' understanding of science, shaped her knowledge of assessing scientific literacy. The didactic orientation shaped Chujai's belief that students would develop correct understanding of science when they paid attention to her explanation. In addition, Chujai's limited knowledge of students' learning process had relation to her limited knowledge of assessment in order to find and interpret students' ideas. Furthermore, the limited knowledge of students' misconceptions and of assessment resulted in her not

assessing students' prior knowledge. Finally, the didactic orientation shaped Chujai's decision by providing extra hours to instruct students in order to help them overcome the difficulties to understand this particular concept.

In summary, Chujai displayed a lack of PCK. She was not knowledgeable in students' learning approach or difficulties. Chujai failed to transform knowledge of conduction of heat to students in an understandable way. She did not know how to put her teaching strategies into a sequence that would help students to learn the concept. In addition, similar to other teachers, Chujai did not demonstrate the understanding about the strengths and weaknesses of teaching strategies, activities, and analogies that she used with students. She did not pay enough attention to whether or not the analogies she demonstrated to students would lead students to misconceptions about the conduction of heat. Lastly, in addition to not knowing about the activities and having inadequate subject matter knowledge on the topic that she taught, Chujai did not get to the main ideas of the concept and made students confused.

Jinda's Implementation, Orientation, and PCK for Science Teaching

Classroom Implementation

On day one of teaching the sound concept, Jinda planned to provide an activity that she learned in the PD. Jinda prepared various types of glass, such as tumbler, brandy, and plastic glass filled with either water or colored water for each group. Jinda indicated that the purpose of doing this activity was to develop students' knowledge that sound is produced by vibration, which could be observed through water vibration. In order to help students see this phenomenon better, Jinda asked students to compare sound and vibration between glasses containing water or colored water. When the students came to

the science classroom, Jinda turned on music for the students. She also asked one student to play a Chinese dulcimer. She asked several questions to students, such as why they hear sound and where does sound come from. Jinda explained to students that in order to answer these questions, they needed to do the activity. Then Jinda explained the activity directions to the students and introduced the materials needed for the activities. Jinda repeated the directions twice in order to ensure that every student had a clear understanding of what they needed to do. Instead of giving observation sheets to the students, Jinda gave a sheet of plain paper to students to report their findings and conclusions. During the activity, Jinda did not provide any directions to the students, but let them independently work within their group. However, when Jinda noticed that the majority of students seemed to not understand the activity, she re-explained the activity directions to them. Jinda walked around the classroom to observe students' performance and to provide some guidance. After finishing the activity, students worked within their group to develop conclusions from the activity. At the end of the activity, Jinda called two representative students from each group, one group at a time, to report their group's work in front of the classroom. Jinda asked students several questions designed to connect the concept that sound is produced by vibration and so, when they see vibration in their glasses that corresponds to a sound that is produced.

Jinda: What happened when you rubbed at the edge of glass?

Students: Sound

Jinda: Where does sound come from?

Students: Glass

Students: Water

Jinda: Why did I tell you to put water in the glass?

Students: To make sound.

Jinda: Did any of you notice what does water look like when you hear sound?

Students: Waving

Jinda: Why did I ask you to put water in one glass and colored water in another glass? Was the sound from both glasses similar?

Students: yes

Jinda: So, why did I ask you to do that?

No answers from the students.

Jinda: In what type of water were you able to see it waving easier? Some students said colored water, but some students said plain water.

Jinda: I put color in water to make it easier to see the vibration. When you rub the glass, the glass will vibrate and make sound. You can see the glass vibrates from water waving.

Jinda: Tell me again what makes sound?

Students: Vibrations.

Jinda: What did vibrate?

Students: Glass

Jinda: How did you know it?

Students: Because water vibrates.

(Jinda, Classroom Observation)

Then, Jinda had students do another activity. She asked students to pair up and to have one of them put their ear on the back of their friend and listen quietly. The students took turns listening to each others' backs. Jinda asked the students whether or not they heard anything. The students replied that they could hear their friend's heartbeat. Next, Jinda asked students to hold fingers to their neck while answering her questions. The students responded that they felt vibration inside their neck. Jinda explained about vocal cords and how they vibrate and make sound. At the end of class, Jinda repeatedly asked students how sound occurs.

On day two, Jinda started her classroom session by reminding students about the previous activities. She gave a blank sheet of paper to each group of students and explained the activities that they were about to do. Similar to day one, Jinda provided clear directions to students twice in order to ensure that they understood the activity. It should be noted that during Jinda's directions, the students carefully listened to her (at the beginning of the school term, Jinda said she and her students came to an agreement that

the students needed to quietly listen to her and when they needed to talk they had to raise their hand. If any of the students did not follow this rule, Jinda would deduct points from the group). For day two, Jinda prepared two activities, which were in IPST Curriculum, for the students. To begin the first activity, Jinda asked the students to fill four flasks with water with different volumes. However, instead of following the activity directions as provided to her, Jinda modified the activity. She asked each student in a group take turns blowing on the edge of each flask instead of knocking at the flasks (as the original directions said to) to see what happened. Before doing the activity, students were sure that they would make sound when they blew on the flask. However, during the activity, the students hardly heard sound. In addition, the findings and the conclusion that the students made were absolutely opposite the results in teachers' guide from tapping the flasks. Jinda asked the students to repeat the activity and suggested that each student blow on each flask with the same amount of energy. With students getting the same results as the first time they did the activity. Jinda decided not to give the correct information to the students right away, but encouraged them to try the activity again at home. Then, Jinda asked the students to do the second activity by covering a box with plastic bag. Jinda asked the students to compare the sound produced by both tight and loose plastic bags. The representative students for each group came to the front of the class and reported their findings. The group findings did not agree. The results from some groups indicated that the sound from a tight plastic was louder than the loose one while other groups indicated the opposite. Again, Jinda did not tell the students which answer was right or wrong, but encouraged them to try the activity again after class.

Science instruction on day three was in the typical classroom instead of a laboratory classroom. Jinda aimed to wrap up for the students what they had learned in the science classroom. At the beginning of the class, Jinda demonstrated to the students the activity that filled four flasks with water. This time, Jinda decided to follow the original activity directions by using a pencil to knock at each flask. Jinda asked students to closely observe what happened to the water while she was knocking at each flask. Jinda asked students to compare the phenomenon in each flask.

- Jinda: Water in which flask vibrate fastest? And water in which flask is slowest?
- Students: Small amount of water vibrates fastest and large amount of water vibrates slowest.
- Jinda: How is sound from these four flasks different?
- Students: The flask that has least amount of water produces highest tone of sound [pitch] when the flask that has largest amount of water produces lowest tone of sound.
- Jinda: What makes sound have different tones?
- Students: water
- Students: weight
- Jinda knocked at the flask that has smallest amount of water
- Jinda: Tell me how fast the water vibrates when you hear the high tone.
- Students: very fast
- Jinda: How about the flask that produces the lower tone?
- Students: slower
- Jinda: So, what makes sound have different tones?
- Students: Vibration of water
- Jinda: What conclusion can you make from this activity?
- Students: When water vibrates very fast, it produces sound in a high tone. When water vibrates slower, the tone of sound will be lower.
- Jinda: Is it necessary that sound is made from water vibration only?
- Students: No

Jinda: So, what could we say then?

Students: High tone is made when matters vibrate fast and low tone is made when matters vibrate slowly.

(Jinda, Classroom Observation)

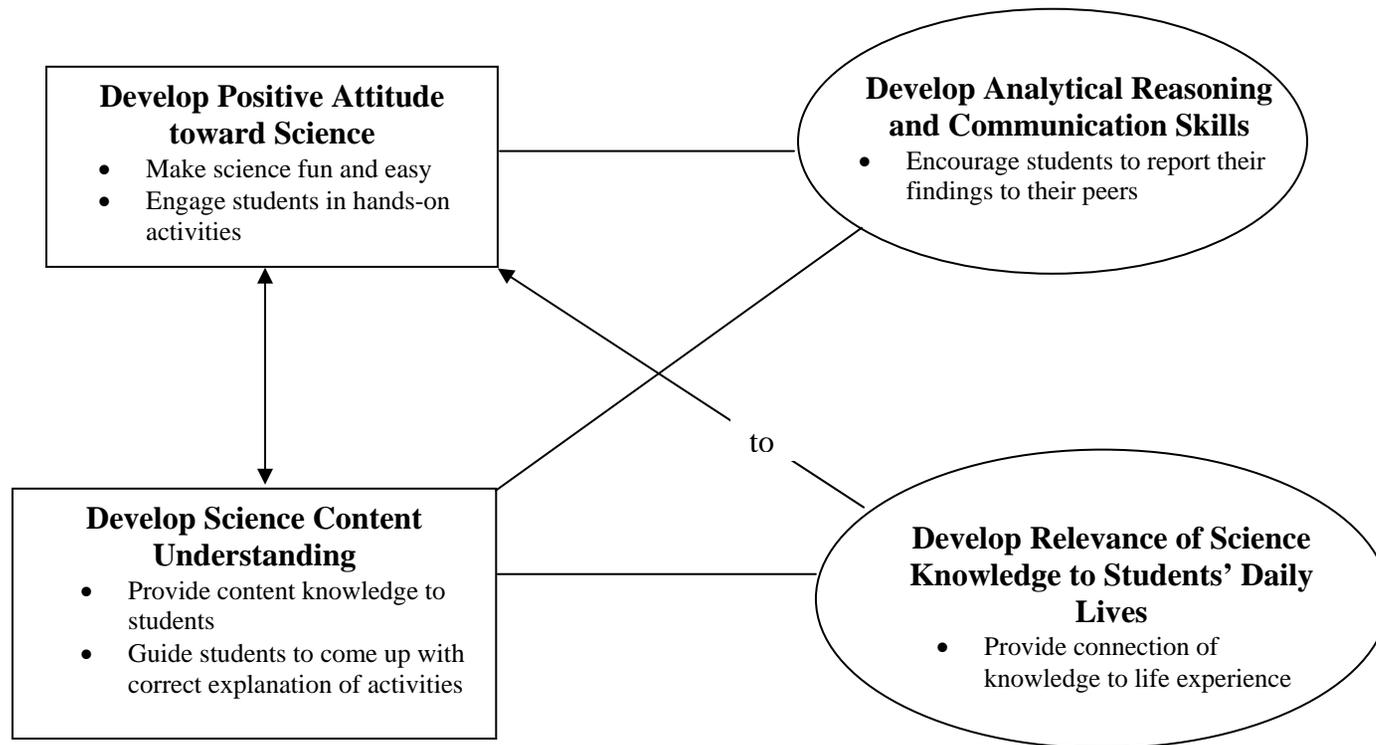
Then, Jinda explained to the students that people used knowledge of pitch to make musical instruments. Jinda asked students whether or not they had ever seen a guitar. She asked students about the differences in the guitar's strings. Then, she asked students to explain what pitch they would hear from the biggest string and from the smallest string. Again, Jinda repeatedly asked students what makes sound and pitch.

Before the end of the class, Jinda gave an assignment to students in order to assess their understanding about this concept. In this assignment of the "sound" instruction, Jinda provided the activity directions that the students did on the first day. She asked the students to write down what types of pitch they expected to hear from brandy glasses that contained differing volumes of water. Jinda walked around the classroom to observe students' working. Jinda noticed that many students still did not write the correct answer on the assignment. At the end of the class, Jinda tried to correct students' understandings by asking them twice about how sound is produced and how they know that.

Teaching Orientation

Figure 17 represents my analysis of Jinda's orientation. I found that, during the interviews and classroom teaching, Jinda's orientation to teaching the concept of sound at the primary level consisted of two central goals, which included 1) developing accurate understanding of science content and 2) creating positive attitudes toward science. Jinda's peripheral goals in teaching this concept were 1) to help students connect classroom knowledge to everyday experience and develop awareness about the phenomenon and 2) develop analytical reasoning and communication skills.

Figure 17. Jinda's Goals for Primary Science Teaching



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□ = central goals; ○ = peripheral goals

วิทยาศาสตร์นี้มันเป็นวิชาที่มีอยู่ในชีวิตประจำวันของเด็กตั้งแต่เล็กๆ เลยคือเหมือนกับสัมผัสได้ เพราะฉะนั้น เด็กจะต้องมีความรู้พื้นฐานทางด้านวิทยาศาสตร์มาก ๆ มันสามารถใช้ได้ในชีวิตประจำวัน

Science is in students' everyday life. They have to live with science, so it is important for them to have fundamental knowledge of this discipline because it is helpful for their lives. (Jinda, Interview #1)

In order to develop students' understanding of science content, Jinda led students to the content knowledge either through questioning, demonstration, or explanation. Jinda expected that students should be able to apply knowledge that had been taught to real-life experience.

เด็กต้องรู้ว่าเสียงเกิดจากอะไร เรียนแล้วเขาควรจะนำไปใช้ประโยชน์ได้ นี่คือจุดมุ่งหมาย ไม่ใช่แค่เรียนเพื่อรู้ว่า เสียงเกิดจากอะไร เสียงมาได้อย่างไร แต่ควรจะไปใช้ประโยชน์ว่า เมื่อรู้แล้วเราควรจะไปใช้อะไรได้น่า

Students must understand how sound is produced. Just knowing is not enough, they should be able to apply this knowledge in their lives. (Jinda, Interview #1)

Although Jinda wanted to help students develop understanding of science, development of positive attitude toward science among her students seemed to be her primary goal for teaching primary science. Jinda indicated that science at primary grades should be fundamental and not difficult.

เด็กต้องสนุก ง่าย เด็กทำได้ ทำให้เด็กเค้าไม่เบื่อ ไม่เครียด เด็กต้องรู้สึกว่ายเรียนวิทยาศาสตร์นี้สนุกนะ มันง่ายนะไม่ใช่ให้เค้ารู้สึกว่ามันยาก เพราะส่วนใหญ่เด็กจะคิดว่าวิชานี้ยาก แต่พอเค้าสนุกและได้ทดลองเค้าจะคิดว่ามันไม่ยาก และเมื่อเรียนแล้วต้องนำไปใช้ในชีวิตประจำวันเค้าได้ เผยแพร่ความรู้ให้คนอื่นได้ ไม่ใช่แค่เพื่อรู้หรือเพื่อสอบ เด็กต้องใช้ทดลองและทำจริงๆ

Students must enjoy learning it. It should not be too difficult otherwise students will get bored. I want to help students to feel that science is easy and fun and they can apply this knowledge in their life. Students should have real experience in learning science and be able to share their knowledge with other people rather than just knowing for the test. (Jinda, Card Sort Activity)

In addition, Jinda mentioned that the activities for primary students should be fun and exciting to them so students would not get bored.

อยากได้อะไรที่เป็น high technology อย่างเรียนเรื่องสัตว์ ได้ผ่ากบ แต่อย่างเรื่องเสียงทำ ยังไงเด็กเค้าจะได้ตื่นเต้น อยากได้กิจกรรมที่อสังการหน่อย คือถ้าเด็กสนุกเค้าก็จะอยาก

เรียน ไม่เบื่อไม่ง่วง ในระดับประถมเนื้อหาไม่ต้องเรียนลึกมาหрок ไว้รอให้เค้าโตกว่านี้
 พร้อมกว่านี้ก่อน ในระดับนี้ควรฝึกทักษะให้เขารู้จักคิดวิเคราะห์และอธิบายได้แค่นั้นพอ
 ไม่อย่างนั้นเค้าจะเครียดและทำไม่ค่อยได้ ไม่ต้อง concept ลงลึกแต่ให้ฝึกทักษะดีกว่า
 ดีกว่าทำให้เด็กจะไม่ชอบวิทยาศาสตร์

Science activities for primary students should be exciting, fun, and use high technology. For example, students will like to do the dissection of the frog to see its anatomy. I think the sound activities are too boring for students. I want to have activities that are amazing for students so they will be happy to learn. I think we should leave content knowledge to the higher levels, but prepare primary students for the laboratory skills and developing positive attitude toward science. We should make students love science. (Jinda, Interview #1)

According to Table 14, Jinda realized that the teaching strategies in scenario 8 and 12 were closer to her teaching techniques.

Table 14

Jinda's Arrangement and Interpretation of the Card-Sort Scenarios

Items	Scenarios	Jinda's Interpretations
8	As a teacher, you want teachers to learn about how sound is produced. You decide the best way to do this is to demonstrate students with various activities to verify a science concept of vibration produces sound. (academic rigor)	"I will bring a Chinese dulcimer to class to play in front of students and ask them how it makes sound. Then, I will allow them to explore activities that I prepare. I agree about having students do many activities because some students can't develop understanding from doing just one activity." (activity-driven)
12	You, as a teacher, have your students first engage in laboratory activities in a book, class discussion. You will end each activity with your explanation of science knowledge beyond those activities. (didactic)	"I won't start by having them to do the activity in the book. Instead, I will use other things, such as games, songs and questions in order to call their attention. I will provide opportunities for students to develop their own explanation of the simple activity. But, if I find the activity results are unclear to them, then I will give an explanation." (didactic)
3	You, as a teacher, set up classroom lessons for a unit on heat conduction. Using resource elementary books, you select a variety of fun, and easy-to-do activities. (activity-driven)	"I'll do the same things as stated in the scenario. I'll also look for activities from other resources, such as Internet because I want students to do many activities instead of one activity for one concept." (activity-driven)
14	Your students have just completed a simple circuit with multiple bulbs. For the next unit on electricity, you ask the students to make the bulbs light using a combination of wire, bulbs, and switch. (guided inquiry)	"This activity is appropriate when students already learn about circuits and know how the circuits work. When they know it, we can let them try to apply their knowledge to solve other problems." (discovery)

Table 14 (continued)

Items	Scenarios	Jinda's Interpretations
5	In an electricity unit, you, as a teacher, give students batteries, bulbs and wires. You encourage the students to find all the possible ways to light the bulb. (discovery)	"This is the way that I like to do because it helps students to develop analytical thinking." (discovery)
11	You, as a teacher, begin a unit on Sound by introducing curriculum, explaining materials, allowing students doing activities, and you explaining the concepts at the end of activities. (didactic)	"I won't explain the curriculum, but I'll start by engaging them with an exciting activity or game or other things. When the students get excited, they will be ready to learn. Then, I'll assign them to do the activities that I prepare for them. Students have to develop their own explanation and conclusion of the activities. I will wrap-up and explain about the content after that." (didactic)

According to scenario 8, Jinda indicated that in her science classroom she liked to provide first-hand experience to students by having them participate in hands-on activities or science projects. She also agreed that students should have opportunities to do many activities addressing a particular concept in order to help them develop a clearer understanding of that concept.

ก็คิดว่าจะเอาขิมมาเล่นให้นักเรียนฟังแล้วถามเค้าว่าเสียงมาจากไหน จากนั้นก็ให้เค้าลองทำกิจกรรมดู อันนี้เห็นด้วยที่ให้เค้าทำหลายกิจกรรม เพราะเราก็เตรียมให้เค้าหลายกิจกรรมเหมือนกัน บางทีนักเรียนเค้าทำกิจกรรมเดียวเค้ายังไม่ทันรู้หรือกว่าอะไรเป็นอะไร ต้องย้าเค้า ให้เค้าทำเยอะๆ
I will bring a Chinese dulcimer to class to play in front of students and ask them how it makes sound. Then, I will allow them to explore using activities that I prepare. I agree about having students do many activities because some students can't develop understanding from doing just one activity. (Jinda, Card Sort Activity)

While Jinda reflected on this scenario, she mentioned her plan for teaching the sound lesson as an example. She stated that she might use only one musical instrument instead of using many instruments. The purpose of using the musical instrument was to encourage students at the beginning of the class to think about how they could hear sound and how the musical instrument made different pitches. Then, she would encourage the students to explore using the activities that she prepared for them.

According to scenario 12, Jinda mentioned that she did not provide explanations and information about the activity to students every time. Rather, she would let the students work within groups to develop their own explanations and conclusions and report their findings and conclusions to the class. She mentioned that:

ฉันนี้กำลังนะ เพราะบางอันก็ไม่ทุกครั้ง กิจกรรมง่ายๆ เด็กเค้าสามารถอธิบายความรู้ออกมาได้เลย ครูไม่ต้องสรุปให้ แต่ถ้ากิจกรรมไหนยากๆ ก็จะช่วยเค้าอาจจะอธิบายเค้าก่อน หรือหลังจากการทดลองตามแต่เนื่อหานั้นๆ

I cannot decide for this scenario because I don't give explanations to students when the activity is simple. However, when the activity is more abstract, I will give explanation or instruct them either before or after they do the activity. (Jinda, Card Sort Activity)

In the second card sort activity, Jinda indicated that she would guide the students to the conclusion of an activity that she thought it was too abstract for the students.

According to scenario 3, Jinda indicated that she agreed with this scenario in terms of selecting easy and fun activities for students. However, she did not select the activity from only one resource, but looked for other activities and information from other resources, such as Internet.

ส่วนใหญ่เราจะเอากิจกรรมในหนังสือที่เรามีให้เรียนของหลายๆ สถาบัน เรายังจะเน้นตามนั้น เราไม่ได้ยึดกับหนังสือเล่มเดียว อย่างบางทีเราก็หาทาง Internet หรือไม่ก็ให้เด็กไปหาแล้วมาเล่าให้ฟัง

I usually select activities from many resources. I don't stick to only one curriculum. Sometime I also find activity or information from the Internet. Or, I ask students to look for information from the Internet as well. (Jinda, Card Sort Activity)

Although Jinda strongly agreed that students should have opportunities to engage in hands-on activity, she did not agree with many scenarios, such as scenario 6, 10, and 15, where students designed their own experiments. Jinda realized that this strategy was crucial in science learning, but she did not believe that primary students could take this level of responsibility. Jinda's comment on these scenarios was based on her teaching experiences. She explained that:

ถ้าเราจะแนะนำให้เด็กทำ แล้วให้เด็กอภิปรายและสังเกตเด็กคงทำได้แต่ถ้าให้เด็กออกแบบเองนี่ค่อนข้างว่าเด็ก ป. น่าจะยังทำไม่ได้ถ้าให้เค้าออกแบบเอง แต่ถ้าเราแนะนำว่าจะทำอย่างไร น่าจะดีกว่าให้เค้าออกแบบเอง ถ้าให้เค้าออกแบบเค้าคงทำกันไม่ได้หรอก บางทีเราเองเรายังนั่งนึกเอ็ง เราจะออกแบบยังไง บางทีครูก็ยังไม่ได้เหมือนกันถ้าไม่มีสื่อแนะนำจากหลักสูตรของกระทรวง บางทีเรายังนึกไม่ออกเลยว่าเราจะทำยังไงดีที่เด็กถึงจะทดลองได้รู้เรื่อง เพราะฉะนั้นเด็กคงจะทำไม่ได้ แต่ก็ยังไม่ได้ทดลองนะว่าเด็กเค้าทำได้มั๊ย เค้าคิดเองอะไรเอง ยังไม่ได้ลองดูว่าเค้าทำได้มั๊ย

I might have students do this activity except design and carry out their own experiment. I think it is too difficult for students, they cannot do it. Sometimes adults, such as me, still have problems with designing activities and teaching that could be easy for students to understand the expected concept. So, I don't think students can do it although I never tried with students before. (Jinda, Card Sort Activity)

Jinda indicated that she never tried to allow the students to carry out their own experiment. This anxiety came from her experience where even she, who had more knowledge than students, still had difficulties in designing an activity that would be appropriate for a particular grade of students. Hence, she did not think that students, who had limited knowledge and experience, would be able to complete this task without teachers' guidance. Thus, it appeared in her teaching that Jinda preferred to provide guided activities to students rather than having them design their own investigations. Jinda's anxiety about students' ability appeared again when she reflected on scenario 5. Jinda's comment on this scenario was that students could do the activity stated in the scenario only when they already had knowledge of electricity and circuit concepts. In other words, Jinda indicated that the students should do other activities that provided basic understanding of how simple circuits worked before doing the activity stated in this scenario.

อันนี้เค้าต้องมีความรู้เรื่องไฟฟ้ามาแล้วไซ้มั๊ยคะ เพราะฉะนั้นเค้าน่าจะทำได้ เราต้องให้เค้ารู้ก่อนว่าวงจรไฟฟ้าต่อยังไง ต่ออนุกรม ต่อขนานอะไรอย่างนี้ ก็ต้องให้เค้ารู้ก่อน พอเค้ารู้แล้วเค้าก็น่าจะทำได้ แต่ถ้าให้เค้าอยู่ๆ มาต่อๆ เลยนี้เค้าไม่น่าจะทำได้นะ มันค่อนข้างยากเรารู้ว่าตัวเองเป็นครูบางทีรู้สึกตัวตัวเองยังค่อนข้างสับสนกับมัน ต้องให้ครูที่เป็นผู้ชายสอนใหญ่ เขาจะเก่ง

To do this activity, students have to learn the electricity unit before. When students know how to make simple and parallel circuits, then I think they can do the activity as stated in this scenario. If they don't know it before, I

think this activity will be too difficult for them and I don't think they can do it. Like myself, I am teacher, but I still get confused about how to make the circuit complete. I still have to ask other teachers who are male because they are good about electricity. (Jinda, Interview #1)

The excerpt reveals that although Jinda wanted to help students to develop skills that were necessary in learning science, such as analytical skills, her anxiety about students' ability caused her to avoid providing opportunities for students to perform science without her guidance.

Furthermore, when she was asked about the purpose in giving students a blank sheet of paper instead of an observation sheet, Jinda's answer showed that the reason for doing this was irrelevant to science instruction. Jinda indicated that many of students had poor writing skills. So, having them write down their results on a blank sheet of paper would help them with the Thai writing skills.

แนวคิดคือเด็กเดี๋ยวนี้เขียนหนังสือไม่ค่อยเป็น ก็เลยอยากฝึกให้เด็กได้หัดเขียนหนังสือ พอได้เขียนก็จะได้จำมากกว่าการเติมในใบบันทึก
Students don't have good writing skills. I want them to improve this skill. Furthermore, students can better memorize when they have to write everything on their own than when they just fill in the blank on an observation sheet. (Jinda, Interview #2)

Through specific interview probes on teaching the sound concept, Jinda wanted students to understand on how sound is produced, the properties of sound, and how people hear sound. In addition, to develop content knowledge on sound, Jinda wanted students to be able to apply the knowledge that they learned to everyday experience, such as keeping themselves away from dangers caused by sounds.

เด็กต้องรู้ว่าเสียงเกิดจากอะไร เสียงแตกต่างกันยังไง ทำไมถึงแตกต่างกัน แล้วทำไมเราถึงได้ยินเสียง ที่สำคัญคือ เรียนแล้วเขาควรจะไปใช้ประโยชน์ได้ควรรู้ว่าเสียงแบบไหนเป็นอันตรายกับหูของเรา
Students must know how sound is produced and how and why we hear sound differently. The most important thing is they need to know what types of sound can be dangerous to them so they can know how to take care themselves. (Jinda, Interview #2)

Although understanding accurate content knowledge in science was one of Jinda's central goals, Jinda mentioned that the current reformed standards required primary students to learn content knowledge in science that was too deep and beyond the students' needs. She indicated that:

รู้สึกเด็กจะได้เรียนยากขึ้น บางทีอย่างเนื้อหาบางเรื่องเขาควรจะเรียนรู้ใน ระดับมัธยม มากกว่าที่จะมาอยู่ในระดับประถม อย่างเช่นเรื่องไฟฟ้าเด็ก ป3 ต้องรู้แล้วซึ่งเมื่อมันค่อนข้างยากเรารู้ว่าตัวเองเป็นครูบางทีรู้สึกว่าตัวเองยังค่อนข้างสับสนกับมัน ต้องให้ครูที่เป็นผู้ชาย ส่วนใหญ่เขาจะเก่ง จำได้ว่าตอนอยู่ประถมมันไม่มีอะไรขนาดนี้หรอก ทำไมมันยากจัง พอ มันยากทำให้เด็กบางทีไม่ยอมเรียนวิทยาศาสตร์เหมือนกันนะ พอยากมันเหมือนเขาทำอะไรไม่ยอมจะเรียนคือให้เขาพร้อมจะรู้ในระดับโตขึ้นกว่านี้หน่อยดีกว่า จะทำให้เขาไม่เกลียดวิชา นี้

I think it [science] is more difficult for students. Some concepts they should learn at middle or high school rather than primary school. For example, I don't agree with having third graders learn circuit and electricity. Based on my experience as a college student, this concept was really confusing to me and I need to get some help from male teachers. I remember that it was not this difficult when I was at primary level. I am afraid that it will make students hate science. We should wait until students are ready. (Jinda, Interview #1)

Jinda stated that although she believed in students' capabilities and their abilities to learn all the concepts that were requested by the standards, she also believed that some concepts, such as circuit and electricity should not be taught at the primary level. She indicated that she felt too much content knowledge would put too much pressure on students to do well and, as a result, they would hate science. Hence, in Jinda's opinion, content knowledge for primary students should be superficially presented through first-hand experiences which were fun and exciting in order to develop positive attitudes toward science. Also, elementary science teaching should emphasize improving students' scientific skills, such as reasoning, communication, and laboratory skills, which they might use later in higher science education.

[เนื้อหา] ลึกไปควรฝึกทักษะให้เขารู้จักคิดวิเคราะห์แค่นั้นพอ ให้เขารู้บ้างแต่ไม่ถึงขนาด ต้องรู้ยาก ๆ มากไปพอเห็นหลักสูตรใหม่ แล้วงงเหมือนกันทำไมเขาให้เด็กเรียนหนักเกินไป หรือเปล่าคือมันค่อนข้างยากไปสำหรับเด็กประถม บางทีเขายังคิดไม่ออกอะไรยังงี้ รู้แต่ว่า

มันมีประโยชน์ยังไง ก็น่าจะพอแล้วไม่น่าจะมาลงละเอียดว่าต่อแบบขนาน ต่อแบบอนุกรม มันไม่ควรจะขนาดนั้น แต่รู้ว่าประโยชน์ของไฟฟ้าคืออะไรดีกว่า ช่วยกันอนุรักษ์ไฟฟ้ากัน ดีกว่า อย่างนี้จะดีกว่า กลัวว่าเด็กจะเครียดและทำไม่ค่อยได้ ไม่ต้อง concept ลงลึกแต่ให้ฝึกทักษะดีกว่า ดีกว่าทำให้เด็กจะไม่ชอบวิทยาศาสตร์ บางทีระดับประถมอะ เนื้อหามันรู้สึก ว่าทำไมจะต้องยัดเรื่องยากๆ มาให้เด็ก อย่างน้อยให้เด็กเค้ารักวิทยาศาสตร์ พื้นฐานประถม ก่อน มัธยมค่อยไปจับยัดให้เค้า ดีกว่ามาเรียนฟิสิกส์ เคมี อะไรอย่างนี้ น่าจะเป็น เออ เรียน แล้วเค้าสนุกเนอะ เอาอย่างนี้ดีกว่า อยากให้เด็กได้เรียนสนุก คือเนื้อหาอย่าไป serious กับ มันมากนัก ถ้า serious แล้วเด็กเค้าเบื่อ น่าจะไปแบบเออมัธยมนุ่นละแล้วค่อยว่ากัน นี่เด็ก ประถมนะให้มันอ่านออกเขียนได้ ให้มันสนุกที่จะเรียนก็โอเคละ

It is too deep. We should emphasize scientific skills at this level. I am disappointed with the new curriculum because it contains too much content knowledge for students. In teaching at the primary level, we do not have to go in depth. Students should only know the part of information that will be helpful for their daily life. Primary students should be trained to develop laboratory skills. We should make them love science rather than hate science. We can just leave the content knowledge to the middle school students. (Jinda, Interview #2)

Jinda revealed that if she could design her science teaching independently, her science curriculum would include general knowledge in science that related to students' life and society.

In summary, like other participants, Jinda displayed multiple primary science orientations, which influenced her teaching. Jinda displayed an activity-driven orientation, which supported her central goal for teaching primary science. Jinda's central goals were to develop accurate science content knowledge and to instill a positive attitude toward science. In order to help the students meet these goals, Jinda chose to use first-hand experience through hands-on activities as the means in her science classroom. Jinda displayed an activity-driven orientation in terms of having students participate in hands-on activities in order to discover the expected outcomes. Jinda's modification of the sound activity revealed that she had limited content knowledge of the concept of sound and did not clearly understand the purpose of doing that particular sound activity. In addition, Jinda preferred to expose primary students to the fun and amazing hands-on activities as a way to make students enjoy learning science rather than to develop

understanding of the concepts. In other words, Jinda saw hands-on activity as a tool to make students love science rather than a tool to facilitate their learning science.

In addition to the activity-driven orientation, Jinda also displayed an academic rigor orientation. Although Jinda did not agree with the standards that covered too many concepts at primary levels, she allocated time for the students to understand the concepts that were in the standards. Jinda used several teaching strategies, such as posing and repeating questions, providing activities, and demonstrations to help students verify the concept of sound. Classroom observations and specific interviews also reveal that Jinda's belief about primary science teaching, her anxiety about primary student's capabilities and her content knowledge in science influenced her decisions in the designing and implementation in the classroom.

PCK for Primary Science Teaching

Knowledge of students' understanding of science. In the sound lesson, Jinda indicated that the concepts involving components of ears and frequency were the most difficult concepts for students. However, it was revealed that Jinda saw these two concepts are difficult to learn because Jinda herself did not have solid understanding of the concepts.

น่าจะส่วนประกอบของหู มันเป็นชีวะ เราไม่ค่อยถนัดมันค่อนข้างที่จะยากพอสมควร ทั้งส่วนประกอบของหูคอว์เดีย ทั้งอะไรสารพัด มันเหมือนกับเป็นการให้เด็กท่อง มันอยากให้เรียนรู้โดยทำยังไง โดยเด็กไม่ต้องท่องให้เห็นจากของจริง มันค่อนข้างยาก เราจะทำยังไงดีอยากได้มันค่อนข้างจะยากมันอยู่ข้างในมองไม่เห็น

The components of the ear are difficult for me to teach because I don't have biology background. I like to have students learn from hands-on activity or real experience, but this concept seemed to be difficult to teach that way because it is invisible. (Jinda, Interview #1)

Thus, she worried that she might not do a good job in facilitating students' understanding of these concepts. In addition, she did not want students to learn by memorizing even

though she did not know ways to help students to understand these concepts without memorization.

Regarding knowledge of student difficulties, Jinda indicated that she did not think students would have any learning difficulties if they had opportunity to do the activity. Similar to other participants, Jinda exhibited limited knowledge of the learning process where prior knowledge and experiences of learners influence learning. This claim is evident when Jinda reflected on scenario 1 during the card sort activity. She did not agree with scenario 1 that had the students draw a picture of sugar in water. Jinda mentioned that this activity was simple and students could do it in the classroom. She thought teachers should allow students do this activity and then discuss as a whole class about the phenomenon they observed.

ใช้ของจริงเลยซิคะ ทำไมต้องวาดรูป เอน้ำตาลมาใส่น้ำให้นักเรียนดูเลย ควรให้เด็กได้เห็นของจริง ทำการทดลองก่อน แล้วมาอภิปรายกันว่าเกิดอะไรขึ้น
Students should see and do it. Why do we have students to draw picture when they can do it by putting sugar into water and observe? We should provide direct experience to students first and then discuss with students about that experience. (Jinda, Card Sort Activity)

Jinda's activity-driven orientation and knowledge about students learned through first-hand experience led her to overlook an other teaching approach that could influence the learning process.

Knowledge of science teaching strategies. Jinda's experiences in science as a learner and as a teacher led to her distrusting students' abilities in controlling their own learning. This belief led to Jinda's decision to use a teaching strategy that required students to follow activity directions closely.

อันนี้ให้สำรวจ แต่ออกแบบการทดลองเราไม่ได้ให้ทำ อาจจะเพราะว่าเรายังไม่มั่นใจในตัวเด็กว่าจะทำได้หรือเปล่า แต่ ป. 5 ก็เลยไม่ค่อยจะเห็นด้วย
I have students do the investigation. I don't have confidence that 5th grade students can design their own experiment. (Jinda, Card Sort Activity)

Thus, Jinda taught science by providing opportunities for students to do activities and create their own explanation about the activities. For the abstract concepts, Jinda provided explanations instead of having students generate ideas. However, Jinda did not demonstrate her knowledge about each step in teaching science in terms of its importance in facilitating students' learning.

Jinda indicated that she worried about teaching the components of ears and she believed that students might have difficulties learning this topic. In order to help students learn this topic, Jinda exhibited knowledge of ways to represent this topic by preparing a PowerPoint presentation on ears. She also prepared a model to represent each component of the ear that functions to enable people hearing. She also asked students to look for information about ears through the Internet.

ทำ power point ให้เด็กเห็นเป็นรูป เราเอาของจริงให้ดูไม่ได้ เราก็จะมีวางพาราที่โรงเรียนซื้อเอาไว้เป็นส่วนประกอบของหู เป็น model ให้เด็กดู เราให้เด็กเค้า search ใน internet แล้วก็ให้ใบงานวางเป็นฐานแล้วให้เค้าเดินดูก่อน 1 รอบแล้วเสร็จแล้วให้เค้าตอบแรกให้ใช้วิธีจำก่อน พอครั้งที่ 2 ก็ให้เขียน คือเด็กเค้าสามารถพูดได้ละ
I prepared PowerPoint presentation about components of ears to students. I will also show the ear model to student and let them remember the ear's components. Then, I will have students write these components on the worksheet so they can remember them. I will also assign students to search for more information about ears. (Jinda, Interview #1)

However, I found that comparing Jinda's teaching strategies for this topic to other topics, she focused on providing information and knowledge to students directly in order to help students memorize components of the ear and their functions.

ดูเหมือนเราคิดเองว่ายาก แต่เด็กเค้ากับเข้าใจ อย่างเรื่องอวัยวะภายในของหู เรามีความรู้สึกสอนยากนะ โดยที่เราคือพอสอนเรื่องเสียงบีบ ตรงนี้เลยหวังว่าเด็กจะเข้าใจมัยวะอะไรอย่างนี้ เด็กจะรู้เรื่องมัยนี้ แต่พอให้เค้าเดินดู model หูแล้วให้ลองจำจากนั้นก็เขียนดูปรากฏว่าเค้าเข้าใจ เค้าตอบได้
It seems like I just think from my side that the components of ears might be too hard for students to understand. I feel like it is difficult to teach and worry whether or not students will understand my explanation. But, after teaching by showing them an ear model, asking them to memorize each

component of ear and write those names on the worksheet, I find that students understand it. They can answer the questions I give to them. (Jinda, Interview #2)

Jinda used the same strategies when she taught the concept of frequency. However, she stated that she did not worry whether or not students could memorize this information. She only wanted students to develop awareness about what types of sounds were dangerous to their ears.

อย่างเรื่องความถี่นี้ก็ค่อนข้างหนักไปเหมือนกัน แต่เด็กเค้าไม่ค่อย serious มากเท่าไร คืออยากรู้แค่เสียงเท่านี้เป็นอันตราย เสียงมันดัง เรานั่นแค่ว่าหนอย่าไปอยู่ในที่เสียงดัง จะไม่ให้จำว่าดังเท่าไรถึงจะอันตราย ให้แค่ฟังแล้วเรารู้สึกรำคาญ อย่างนี้ก็อันตรายแล้ว เราไม่เน้นให้จำแต่เน้นที่เค้าใช้ชีวิตประจำวัน

I think teaching frequency at the primary grade is too much. But, I am not too serious with it. I just want my students to know the danger of loud voice, so they can take care themselves about safety. I won't emphasize making my students memorize that information, but I will help them to apply knowledge to their life. (Jinda, Interview #2)

Jinda's instruction on the concept of pitch revealed that she had modified the activity by having students blow on top of each bottle containing water instead of knocking it. This reveals that in addition to her limited subject matter knowledge, Jinda also displayed limited understanding of the activity that could help students to develop understanding of pitch. She did not understand the relationship between the activity and the concept of vibration and pitch.

เพราะว่าเอ้ ทำไมเราได้แต่ใช้มือเคาะ ทำไมไม่ใช้อย่างอื่นดู ลองดูได้มัย เคยมีอยู่ที่ที่เรา ล้างขวดแล้วเราลองเป่า เราก็เอ้ มันก็มีเสียงนี่ ลองให้เด็กลองเป่าดูสิ ซึ่งก่อนทำเราก็ลอง เป่าดูนะซึ่งมันก็มีเสียงนะ

I wonder why we have to knock it only. Can we use other methods to make sound? Then, I know that when we blow at the top of bottle, it has sound. I did a pre-lab before having students do it, and it worked. So, I tried this new method with my students. (Jinda, Interview #2)

Jinda believed that this activity did not work because students did not have as good skills as an adult in order to perform well on the activity.

เพียงแต่เด็กเค้าอาจจะยังสังเกตได้ไม่เก่งเท่ากับเราเท่าไร แล้วบางคนประหม่าเลยเป่าแบบเบาๆ แล้วบางคนเป่าแต่ละขวดด้วยแรงไม่เท่ากันมันก็เลยเกิดความแตกต่างกันอย่างเห็นได้ชัด

They didn't observe carefully. Unlike us, they don't have good skills. Some students were shy to blow the bottle so they blew it gently when some students blew each bottle differently. So, the results were different from what it supposed to be. (Jinda, Interview #2)

Knowledge of science curriculum. Based on the interview and card sort activity with Jinda, she did not clearly demonstrate her understanding about curriculum. Jinda only determined that the new science curriculum was more difficult for students than the previous one. Jinda indicated that the content knowledge in this curriculum was too advanced for teaching at primary grades.

เนื้อหามันรู้สึกว่ามันจะต้องยัดเรื่องยากๆ มาให้เด็ก มันยอมค่อยไปจับยัดให้เค้า ดีกว่ามาเรียนฟิสิกส์ เคมี อะไรอย่างนี้ น่าจะเป็น เออ เรียนแล้วเค้าสนุกเนอะ ส่วนเนื้อหาสิคะ ค่อยไปไว้ มันยอมมันละแล้วค่อยว่ากัน นี่เด็กประถมนะให้มันอ่านออกเขียนได้ ให้มันสนุกที่จะเรียนก็พอแล้ว

I don't understand why they have to put difficult things in elementary grades, such as physics, chemistry. I think these two areas of science should be included in middle or high school rather than in elementary levels. Science teaching at elementary grades should be fun, develop writing and reading skills. That should be enough. (Jinda, Interview #2)

During the interviews with Jinda, she did not show an appreciation of the new curriculum. She indicated that she wanted the curriculum to reduce content knowledge and get rid of some concepts, such as electricity. Jinda believed that knowing content knowledge in depth might not be the first priority in teaching science at the primary levels.

Knowledge of assessment of scientific literacy. Jinda displayed her general knowledge about assessment. She indicated that she adopted several assessment methods to assess students' understanding, including student-generated products, attention and responses to questions, and scores on tests.

ก็มีใบงานให้นักเรียน ใช้วิธีสอบถามเพราะบางคนเขียนไม่เป็นถ่ายทอดไม่เป็น แต่เค้าพูดได้อย่างเด็กป. 4 เนี่ยบางทีเค้ายังเขียนหนังสือไม่ได้ เพราะฉะนั้นเราจะใช้วิธีแค่ทำข้อสอบข้อเขียนนี่ไม่ได้ ต้องมีการ observe ขณะทำการทดลองเด็กสนใจมากแค่ไหน พอทดลองแล้วได้ผลถูกต้องมั๊ย แล้วเด็กสนใจที่จะซักถามมั๊ย คือมันต้องหลายๆ อย่าง สอบอย่างเดียว

ไม่ได้ เพราะเด็กบางคนไม่สามารถอธิบายเป็นการเขียน เหมือนกับให้เราเขียนเรียงความนะ
ไม่เคยเขียนได้สักที เพราะฉะนั้นใช้วิธีสอบข้อเขียนอย่างเดียวคงเป็นการทำร้ายเค้า
I use many ways, such as providing worksheet, and questioning. Some
students are not good in communicating through writing, but they can
orally explain. Students at some grades, such as grade 4, cannot write
properly. So, I cannot assess them from only testing. I also do authentic
assessment by observing their attention and interaction during classes. If
we use only one method, it means we are hurting students. (Jinda,
Interview #2)

However, Jinda did not clearly exhibit her knowledge of specific instruments or activities that she used during teaching the sound unit to assess important aspect of students' learning.

In summary, Jinda exhibited poor PCK. She did not have enough understanding about students' understanding of the sound concept that she taught. She did not display knowledge about either students' learning difficulties or misconceptions of the sound concept. The difficulties about the components of the ear that she mentioned during the card sort activity and the interview were due to her limited subject matter knowledge in biology. Thus, she felt it was difficult for her to teach this topic. Jinda also exhibited poor knowledge of teaching strategies, curriculum, or assessment. She did not explicitly demonstrate the strengths and weaknesses of the teaching strategies and assessment instruments she used. In addition, it is evident that her lack of subject matter knowledge influenced the effective use of other types of knowledge. For example, Jinda did not like to have students learn through memorization. However, her lack of subject matter knowledge in biology led her to teach the ear lesson through rote learning. Furthermore, poor subject matter knowledge in the sound concept led her to modify the activity such that it did not support the concept that she expected to teach.

Wanna's Implementation, Orientation, and PCK for Science Teaching

Classroom Implementation

Wanna was going to teach concepts on the properties of liquids and gases to fifth grade students during my observations of her teaching. On day one, Wanna asked her students whether or not they could give names of types of matter that were not in a solid state. Students raised their hands and gave several names. Then, Wanna told students that they were going to explore the properties of matter in the liquid state. Wanna recalled students' knowledge about properties of solid by asking students:

- Wanna: Does matter in solid phase have mass?
Students: Yes.
Wanna: Does it have volume?
Students: Yes.
Wanna: How is its volume?
Students: Consistency. Not change by its container.
Wanna: How is its shape?
Students: Consistency.
Wanna: How about matter in the liquid phase? Do you think it have mass?
Students: Yes.
Wanna: Are you sure? How about volume? Is it consistent?
Students: No [do not sound confidently]
Dang: Do you mean 2 liquids are mixed together or only one liquid?
Wanna: Only one liquid. Does it change volume when you change the container?
Dang: So, it is consistent because it is the same liquid then no matter how many time you change the container, its volume is still the same.

(Wanna, Classroom Observation)

Wanna asked other students whether or not they agreed with Dang, a student who was a school representative for academic competitions. When Wanna saw most students agreed with what Dang said, then she asked students to read the activity directions. The activities that Wanna provided for the students were from IPST Curriculum. These activities were

the same activities that Wanna participated in during the PD. After students finished reading, Wanna asked students to explain to her what they had to do rather than her explain about the activity to the students. For example, instead of explaining to students about the process of finding the mass of water and letting students do the activity, Wanna asked students to explain the reasons for their actions. Wanna also asked students that:

Wanna: Why can't we just weigh water without a graduated cylinder?

Students: Because water will spill over.
(Wanna, Classroom Observation)

After Wanna ensured that students really understood what they had to do, she allowed them to perform those activities independently while she walked to each group of students. When students finished all activities, Wanna gave a (18' W x 24' L) whiteboard to each group of students and asked them to design a table that would represent their findings. When Wanna noticed that all groups finished this task, she asked each group to put their board in front of the classroom. Wanna asked students to vote for each table and gave the reason of their decision. At the end of class, Wanna asked students to orally explain their findings and provide a comparison of the properties of liquid to solid.

On day two, Wanna gave a problem sheet to each student. The problem had a picture as shown in Figure 18.

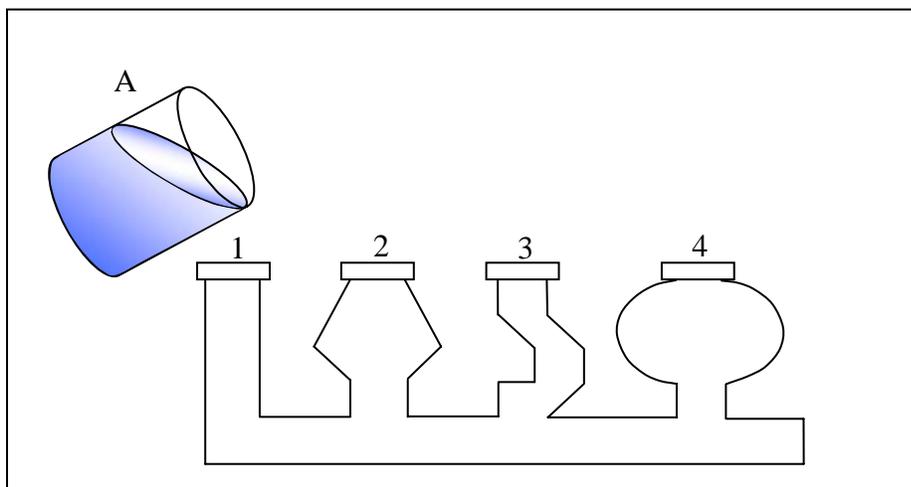


Figure 18. Problem for Assessing Student' Understanding of the Properties of Liquid

Wanna asked students to color the picture that represented the level of water after it was poured from container A to container 1. Wanna adopted this activity from another resource. She used this activity to elaborate students' understanding about liquid. Wanna allowed students to do this activity for about 10 minutes. While students were coloring the picture, Wanna observed each student and noted that students colored the picture differently. Then, Wanna asked some students to volunteer to explain the reason behind their coloring. Several students raised their hands. However, Wanna picked students whom she noted had thought differently about the pattern of water flowing into each tube and its level.

Wanna noticed that students displayed a variation of ideas about water flowing. She allowed students to discuss and ask questions. Instead of answering students' questions herself, Wanna asked other students to answer their peers' questions. Wanna provided about 15 minutes for questions and discussion then she provided an explanation to students and showed a picture by some students that had the correct answer. After

Wanna explained to students, she asked whether or not students agreed with her. A portion of discussion between Wanna and students is shown:

Wanna: When we pour water from container A into tube 1, the air pressure over tube 1 will push water down to the tube and fill the horizontal tube. Then, the remaining water will be pushed into tube 2, 3, and 4 at the same time. At the end, each tube will have the same level of water.

Wanna: Does anyone doesn't agree with this explanation?
Several students raised their hands. Then, Wanna asked Sombat, one of those students.

Sombat: I don't think each tube will have same the level of water because they have different shapes.

Wanna did not respond to this comment, but called another student, Pong.

Pong: Tubes 2, 3, and 4 should have air pressure over each tube like tube 1, why does water in the horizontal tube still go up into the tubes?

Wanna: Because there was plenty of water in tube 1, so it flowed down.

Pong: Does water in tube 1 replace air in tubes 2, 3, and 4?

Wanna: Yes.

(Wanna, Classroom Observation)

Then, Wanna decided to stop the conversation and asked students to write down their conclusion regarding the properties of solid and liquid in their journal. She did not come back to Sombat's question. Instead, Wanna gave a whiteboard to each group of students and asked them to design a table that presented a comparison of properties of liquid and solid. Similar to the previous day, Wanna had students vote for the table that had the best presentation. Wanna asked several of the students to read their conclusion about the properties of liquids. The majority of students asked Wanna about the meaning of molecule when one student used this word in his conclusion. Wanna used an analogy of students holding their hands tight and loose to represent the molecules of solid, liquid, and gas.

Wanna taught the property of gases on day three of my observation. Wanna's teaching strategies on this topic were different from those used to teach about liquids. Wanna stated that she was forced by timeframe (during that month there was an unexpected issue that caused schools in Bangkok area to be off for several days). Thus, Wanna only had 1 hour to teach the concept on gases. The activities of gas concept were selected from the IPST Curriculum, which also were the same activities that the PD provided for teachers. Unlike the liquid activities, Wanna told students what they should observe during the activity. Rather than allowing for a class discussion, Wanna decided to explain the activity directions to students before allowing them to participate in the activities. However, Wanna still provided opportunities for students to develop their own explanation from doing activities. She also allowed students to ask questions. Rather than answer those questions herself, Wanna asked other students in the classroom to help answering the questions. Regarding the activities, some students did not totally agree with their friends' or Wanna's explanation. However, unlike day two, Wanna did not provide an opportunity for those students to share their ideas. Instead, she decided to ignore those questions and moved on to the next planned activity. In order to help students visually understand that gas molecules spread over the container, Wanna demonstrated an activity, which she chose from other resource, by lighting a joss stick and putting it in a bottle. Wanna asked student to observe smoke of the joss stick. Wanna asked students if the smoke represented gaseous molecules, how they would conclude the property of gas in terms of its volume. At the end of the class, Wanna asked students to write about the property of gases based on the activities in their journal and hand to her.

Teaching Orientation

Figure 19 represents my analysis of Wanna's orientation. I found that Wanna's orientation to teaching states of matter topic consisted of two central goals, including 1) developing students' understanding of science content and 2) developing scientific skills necessary for doing science. Wanna's peripheral goals for teaching primary science were to 1) develop understanding of phenomena and making connection of this understanding to students' experience and 2) prepare students for academic competitions at the local and national levels.

Wanna stated that the main purpose of teaching science at the primary level was to help students understand phenomena because they were around these things. Also, Wanna said that science is fundamental knowledge that students need to know. However, science content knowledge for primary students should not be too abstract; rather the content should be familiar to students or closed to their life. As Wanna said:

ควรจะทำสิ่งที่ยู่ใกล้ตัวเขามากที่สุด ถ้าพูดถึงใกล้ตัวบางทีเขานึก เราก็ไม่รู้ว่าเขานึกอย่างไร เรานึกหรือเปล่า อย่างเราบอกอะไรเขาไป เขาไม่เคยเห็นเขาไม่เคยอะไร เขาก็อาจจะนึกไม่ตรงกับเราก็ได้ดังนั้นก็ควรเอาสิ่งใกล้ตัวที่เขาสามารถรู้ สามารถเห็นจับได้อะไรได้ จะทำให้เขามีประสบการณ์ดีขึ้นกว่าเดิม

To teach any topics, I will start from something that is close to students' experience. Because I don't know if I talk about something that they have never seen, they will understand what I am saying. They may think something differently to what I anticipate them to do. So, I will make sure that students know or have some ideas about my talking. And, I think doing this way is appropriate in that I can help students to develop understanding about the phenomenon that they already have experienced.
(Wanna, Interview #1)

Wanna also indicated that students should have opportunities to develop skills necessary for doing science. To meet this goal, Wanna designed her teaching by having students participate in hands-on experiences. Furthermore, Wanna stated that in the second term of school year she would provide laboratory testing for her students. Each student picked the

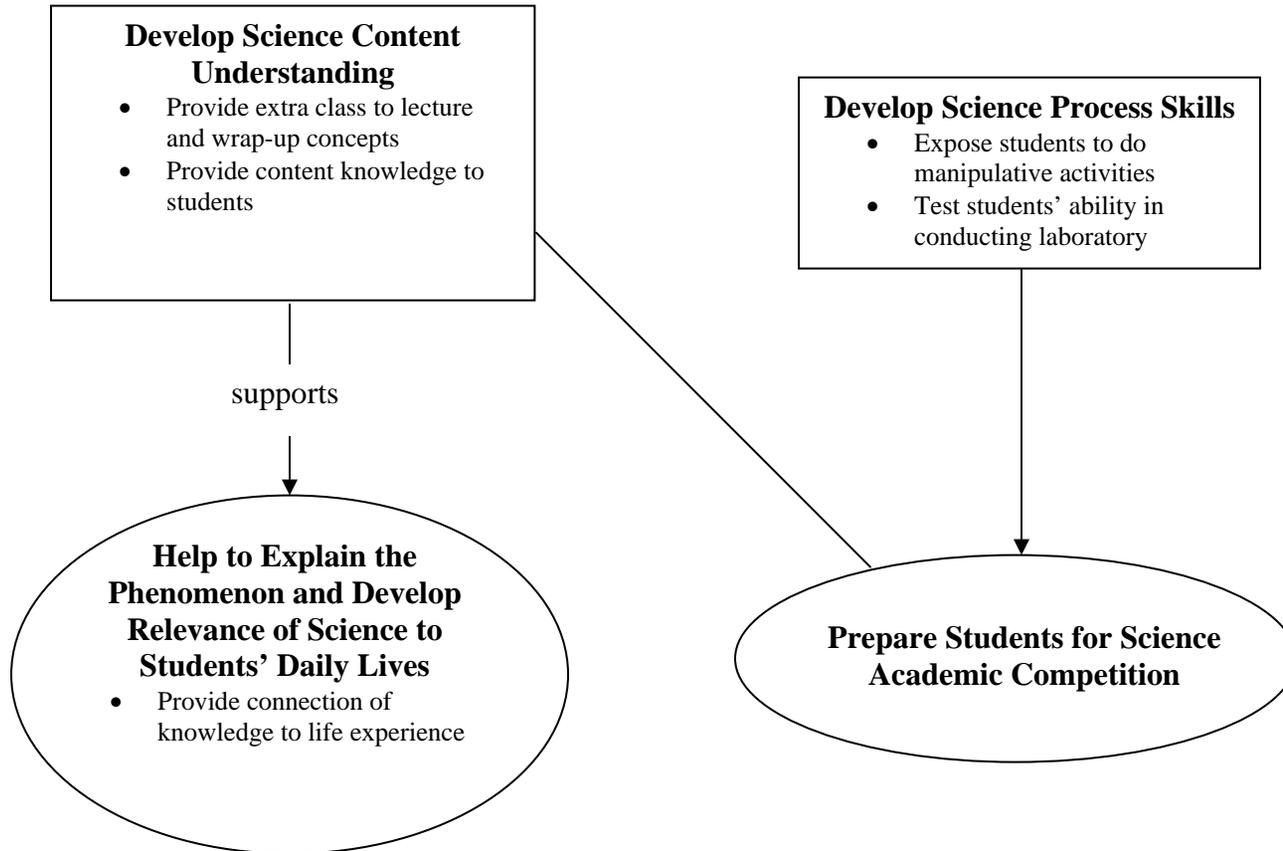
topic through drawing. Then, they had a week to design and prepare an experiment on that topic.

เวลาอย่างเรียนเวลาทดลอง ถ้าเวลามันพอก็จะให้เขาออกมาทดลอง ส่วนมากจะเป็นเทอม 2 เพราะได้ทดลองมาเยอะแล้ว เค้จะจับสลากให้เขาทดลองเรื่องนี้เขาจะต้องเตรียมอุปกรณ์อะไรมาบ้าง แล้วหาว่าทำการทดลองยังไง ดำเนินการยังไงและจะสรุปอย่างไรให้เตรียมตัวมาอาทิตย์นึง เราเอาชื่อเรื่องให้เขา เช่น เรื่องแรงดันอากาศเขาจะใช้อะไร เพราะมันมีได้หลายอย่าง เขาจะเลือกเอาแบบไหนล่ะ เขาก็จะทำกันได้ดีโรงเรียนเราก็มีส่งนักเรียนไปแข่งกระบวนการทางวิทย์ ก็ได้รางวัลมาเยอะ

In the second school term, I will assign students to prepare for performance testing. Students will draw for a topic that they have to prepare. They already did the activities on those topics in the first term. So, they just go back to the book and prepare materials. Some topics have many activities, so students can decide what activity they want to do. I think students did a good job on this task. In addition, our school always sends students for competitions so we have to train them. (Wanna, Interview #1)

Wanna indicated that this strategy helped students develop laboratory skills and also prepared them for competitive events.

Figure 19. Wanna's Goals for Primary Science Teaching



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□ = central goals; ○ = peripheral goals

In regard to Wanna’ reflections on the scenarios in the card sort and her interviews, Wanna would begin her class by calling students’ attention using several techniques, such as asking questions, telling a story, or playing games. Wanna either informed students to read activity instructions before they came to class or within a class. Before having students do an activity, Wanna would make sure that students understood what they had to do by repeating the activity instructions to students or asking students to explain to her about the instructions. At the end of the activity, Wanna allowed students to discuss their findings from the activity. Wanna ended her class by providing an accurate explanation of the activity to the students.

Table 15 shows Wanna’s arrangement and reflection on card sort scenarios that she thought they closed to her teaching strategies.

Table 15

Wanna’s Arrangement and Interpretation of the Card-Sort Scenarios

Items	Scenarios	Wanna’s Interpretations
8	As a teacher, you want students to learn about how sound is produced. You decide the best way to do this is to demonstrate students with various activities to verify a science concept of vibration produces sound. (academic rigor)	“I will start from something that is close to them, such as having them to touch their neck and say something. When they have ideas about vibration, then I will move to other activities. I agree to use many activities with students so they will see many examples. To teach this concept, I will use activities, such as a brandy glass or musical instrument in order to help students develop clear understanding about the concepts.” (academic rigor)
10	You, as a teacher, want students to learn the heat conduction. You decide to ask your students to observe and record about the material used for cooking utensil. Then you and students design an activity around the question, “What are the best materials in making cooking utensils. (project-based science)	“I did this activity before. I used a spoon activity from IPST curriculum. Students can explain what materials are conductors and insulators. Then, I will link to their life. Students know why a pot needs to have a handle. They know if they want to carry a pot that doesn’t have a handle, how to do it.” (academic rigor)

Table 15 (continued)

Items	Scenarios	Wanna's Interpretations
4	When doing laboratory activities, you provide students with clear, easy following, step-by-step directions for the activity procedure. (activity-driven)	"I will explain activity directions to students. Sometime I design a data table for them or give an observation sheet to them. Students need to know what they have to do about the activity. Otherwise, they can't do it correctly." (didactic)
15	You, as a teacher, have students observe a music instrument and generate questions about how sound is produced. Each group designs and carries out their own experiment to test a hypothesis related to the group's questions. (inquiry)	"Students can create hypotheses. But, I don't have students design their own investigation. I use activity kits that IPST designed. Instead, I encourage students to design their own data table sometime because students have seen many examples from books. So, they should be able to do it." (activity-driven)
3	You, as a teacher, set up classroom lessons for a unit on heat conduction. Using resource elementary books, you select a variety of fun, and easy-to-do activities. (activity-driven)	"I will select activities from many resources. The activities need to be exciting and amazing. I will ask students to compare these activities to the activities in IPST curriculum." (activity-driven)
5	In an electricity unit, you, as a teacher, give students batteries, bulbs and wires. You encourage the students to find all the possible ways to light the bulb. (discovery)	"To teach this topic, I will encourage students to bring other objects that students think might conduct electricity, such as buckle and necklace. Students get surprised by doing this because they don't know before that these objects conduct electricity. They know that buckle and necklace are made of metal, so they can conclude that metal conducts electricity." (discovery)

According to scenario 8, Wanna did not see this scenario similar to her teaching science during the first card sort activity because she did not like the activity in the scenario. Wanna indicated that the best way to help students understand that sound is produced by vibration was to have them touch at their neck while they were talking. However, during the second card sorting, Wanna was asked to consider closely the teaching strategies in this scenario. After reading this scenario again, Wanna rearranged the group to "like me" group because in teaching a particular concept she also selected a variety of activities for the students to do in order to understand the concept.

จริงๆ ที่ใกล้ตัวเด็กที่สุดคือคอเค้านี้แหละ ให้เค้าจับดูแล้วตะเบ็งเสียง เค้าจะรู้เลยว่ามันสั้น คือส่วนมากจะให้เค้าเริ่มทำตรงนี้ก่อนแล้วค่อยไปอย่างอื่น แต่เห็นด้วยนะที่ใช้หลายๆ กิจกรรม อย่างพอเค้าจับคอแล้ว พอจะรู้แล้วว่ามันสั้นนะ เราก็ไปให้เค้าทำกิจกรรมอื่น อย่าง

กิจกรรมแก้วน้ำ หรือเครื่องดนตรี ค่อยไปตรงนั้น มันจะทำให้เค้าเห็นชัดขึ้นไง คิดว่าเริ่มจากที่ใกล้ตัวเค้าที่สุดก่อนดีกว่า

I will start from something that is close to them, such as having them touch their neck and say something. When they have ideas about vibration, then I will move to other activities. I agree to use many activities with students so they will see many examples. To teach this concept, I will use activities, such as a brandy glass or musical instrument in order to help students develop clear understanding about the concepts. (Wanna, Card Sort Activity)

Wanna stated that teaching strategies in scenario 10 were similar to her teaching techniques. However, her comments on this scenario revealed that she had a different orientation than intended by this scenario. She explained that:

จากการที่ให้เค้าทดลองตาม สสวท. เค้ายกมือตอบได้ว่าอะไรร้อนเร็วกว่ากัน เสร็จแล้วถามเค้าว่าถ้าเอาหม้อต้มน้ำมาจากสเตนเลส ดินเผา หรือหม้อเคลือบ อันไหนน้ำจะเดือดก่อน เค้าก็ตอบได้ อย่างการทดลองเนี่ยก็จะอธิบายว่านักเรียนต้องทำยังไงเป็นขั้น แล้วก็บอกเค้าว่าในการทดลองบางทีมันมีอันตรายให้ระวัง เสร็จแล้วเราก็จะสอนเค้าว่าเค้าควรเลือกใช้ภาชนะจากวัสดุประเภทไหนจึงจะปลอดภัยกับตัวเค้า

I used a “spoon activity” in the IPST Curriculum. Students can explain what materials are better conductors than the other. I asked students if they boil water in pots made from different types of materials, such as stainless steel and clay, water in which pot will boil first. Before students do the activity, I will explain the direction and safety to them clearly and after that I will ask them about application. (Wanna, Card Sort Activity)

After reading this scenario, Wanna quickly put this card in the “like me” group and stated that she already did this activity with students. Wanna explained that she used a “spoon activity” that was in the IPST Curriculum rather than encourage or work with students to design their own experiment. Wanna also mentioned that she would ensure that students clearly understood the activity directions before having them do the activities. In addition, at the end of activity Wanna helped students to connect the activity results to their everyday experience by explaining to them how they should select and use any utensil safely.

อย่างนักเรียนบางคนนี่เค้าเอาแก้วสเตนเลสมาตีมันมึง โรงเรียนเราจะมีแจกนมให้นักเรียนดื่ม เราก็จะถามนักเรียนว่าการที่เอาแก้วสเตนเลสมาใช้ตีมันมึง จากที่เราได้เรียนมาแล้วนะ แล้วแก้วแบบไหนน่าจะปลอดภัย เราก็จะสอนเค้าว่าเค้าควรจะใช้แก้วแบบไหนมาตีมันมึง

Some students bring stainless steel to class to drink milk. Our school will provide hot milk to students on every afternoon. I led the discussion about this by asking them that from what activity they did, should they use a cup that is made of stainless steel to drink hot milk. I also asked them what types of cups should be appropriate. (Wanna, Card Sort Activity)

Wanna also stated that scenario 15 was close to her teaching. However, similar to her reflection on scenario 10, the way she explained about her teaching was different from the strategies in this scenario. Wanna indicated that she did not have students design their own experiment. Instead, she encouraged students to design the observation table. Wanna indicated that she was not sure whether or not students would be able to design the experiment. But, she stated that they were able to design the table to represent their data because they saw some examples in the books.

ออกแบบการทดลองนี้ไม่ได้ให้ทำ ไม่รู้เค้าจะทำกันได้มั๊ย แต่อย่างออกแบบใบบันทึกนี้ก็
ให้เค้าทำ นอกเค้าว่าให้ลองออกแบบเอง บางทีก็ให้เค้าแข่งกันเปรียบเทียบว่าอันไหนดูง่าย
กว่ากัน เพราะเค้าเห็นตัวอย่างในหนังสือบ้าง พอให้ออกแบบเองเค้าก็จะพอคิดเป็น
I don't have them design experiments, but encourage them to design their
own data table sometimes because students have seen many examples
from books. So, they should be able to do it. (Wanna, Card Sort Activity)

Wanna also indicated that students were able to determine what table would best represent the data and be the easiest to understand.

In regards to scenario 3, Wanna indicated that although she agreed that the teacher should choose easy and fun activities for students, and she did not select the activities from only one resource. Wanna mentioned that when she designed her plan of teaching, she would look at other resources in order to find activities that were exciting for students.

อันนี้จะเอามาจากหลายๆ เล่ม ไม่ใช่เล่มเดียว ดูของหลายๆ บริษัทแล้วเลือกกิจกรรมที่
แปลกๆ น่าสนใจมาลองให้เด็กทำ แล้วให้เค้าเปรียบเทียบกิจกรรมนี้กับกิจกรรมในหนังสือ
เรียน
I will select activities from many resources. The activities need to be
exciting and amazing. I will ask students to compare these activities to the
activities in IPST curriculum. (Wanna, Card Sort Activity)

Wanna put scenario 5 last because she indicated that students could do this activity in the classroom. However, when asked to focus closely on teaching strategies used in the scenario, Wanna took more time than during the first card sorting task to think about the scenario. Then, she mentioned that boys would like this activity more than girls. This would be especially true of students who had experience playing with their toys. Wanna indicated that instead of having students talk about their experiences, she might ask students to think about equipment that need to use electricity in order to make it work. Then, she would provide information about circuits and electricity before allow students to do activity.

อันนี้ได้เพราะเด็กบางคนโดยเฉพาะผู้ชายเค้าจะมีความรู้เกี่ยวกับการต่อไฟของเล่นของเค้า เพราะฉะนั้นถ้าเลือกคนที่มีประสบการณ์ในการต่อของเล่นต่อไฟฟ้าอะไรอย่างนี้ให้เค้ามาทำ ก็ให้เค้ารู้จักการต่อวงจรปิดหรือวงจรเปิด สำหรับการสอนเรื่องนี้โดยทั่วไปการนำเข้าสู่ บทเรียนอาจจะเริ่มด้วยเครื่องใช้ไฟฟ้า ของใช้ในบ้านอะไรที่ต้องใช้ไฟฟ้าบ้าง จากนั้นครูก็ มาให้ความรู้ต่อไป แล้วให้เค้าทดลองต่อดู
Students can do this activity, especially boys, because they have experience playing with their toys. In general, to teach this topic, I will discuss with students about the electric devices in their house. Then, I will provide knowledge about electricity and circuits and then have students do the activities. (Wanna, Card Sort Activity)

Wanna demonstrated that the teaching technique used in this scenario was more appropriate for the students who already had experience in making electrical circuits. However, some students who did not have this kind of experience might not be able to make circuits on their own without the teachers' explanation. Wanna indicated that if she had to teach this topic, she would provide basic knowledge on electricity and simple circuits to students prior to allowing them to do the activity stated in this scenario. Wanna's reflection on this scenario partly came from her experiences learning this concept when she was a student, which influenced her belief about gender equity.

During my analysis, I found that Wanna displayed dual beliefs about the teacher's roles in teaching science; these beliefs contradicted to each other. During the interviews, Wanna indicated that it was not necessary for the teacher to know everything.

บางครั้งเราต้องเรียนไปกับเด็ก เราไม่รู้ทุกอย่าง บางทีเราก็ไม่หาคำตอบให้เค้าหรอก ให้เค้าไปหาเองแล้วมาเล่าให้เพื่อนเล่าให้เราฟังด้วย ซึ่งเราก็เรียนไปกับเขานั้นแหละ แต่เราก็ไม่บอกเค้าหรอกนะว่าเราไม่รู้

Sometimes we have to learn with students. We don't know everything. I don't give the answers to students every time. Instead, I encourage them to find the answer and come to share with me and their peers. But, I don't tell them that I don't know the answer. (Wanna, Interview #1)

Wanna mentioned that whether or not teachers knew the right answer; they should allow students to explore phenomena based on their interest. On the other hand, Wanna displayed her anxiety about teaching the concepts, such as electricity, and other physics concepts, that she did not have good experience with when she was a student. Wanna indicated that she did not want to be unknowledgeable in front of students. Wanna indicated that although she mainly used IPST Curriculum, she still needed to look for activities or content knowledge from other resources because some students took extra tutorial class after school or during weekends. So, these students often talked about what they learned at the tutorial class with their peers or with Wanna herself. Thus, she needed to prepare by looking for the information that students might ask.

บางทีเราไม่รู้ เราก็ไม่กล้าให้เด็กทำกิจกรรม เพราะกลัวเด็กถามแล้วตอบไม่ได้ หรือตอบผิดไปก็ไม่ดี หรือบางครั้งเราก็ต้องเพิ่มเติมให้เขานอกเหนือจากหนังสือ นอกเหนือจากการทดลอง บางอย่างต้องให้ความรู้เพิ่มเติมเค้าไป เพราะบางคนเค้าไปอ่านเจอในหนังสือ หรือเจอในทีวี เค้าจะได้รู้ หรือเด็กบางคนเค้าไปเรียนพิเศษมาเค้าก็เอามาเล่า เอามาถาม Sometimes when I don't know about the concepts, I don't dare to have students do the activities because I am afraid that I can't give the answer that would help them to understand when they ask questions. It isn't good if I give them wrong answers. Sometimes I have to add knowledge beyond the curriculum because some students take extra tutorial classes and they often ask questions that are not in the curriculum. (Wanna, Interview #2)

In summary, Wanna displayed two elementary science teaching orientations, which were academic rigor and discovery orientations. Wanna held the academic rigor orientation when she encouraged students with questions or activities that help students to understand the relationship between particular concepts and phenomena. During the observation of her teaching, I found that Wanna challenged students with questions and problems in order to help students understand the concepts of liquid and gas. She also used activities--a joss stick activity--and also the analogy of having students to hold their hands to represent the molecule configuration of each state, to help students to understand the concept of properties of gaseous state. These teaching practices of Wanna also were supported by her other orientation toward science teaching, the discovery orientation. Other evidence to confirm that Wanna displayed a discovery orientation was showed when she reflected on scenario 13 during the card sort activity. Although scenario 13 represented a guided inquiry orientation, Wanna's reflection on this scenario was toward a discovery orientation when she indicated that the purpose of this activity was for students to discover how the Thai flute makes sound rather than develop the students' process of thinking. However, Wanna did not put this scenario in the group that was close to her teaching style.

ในขลุ่ยจะมีเสียงสูงเสียงต่ำก็ควรให้เด็กได้รู้ว่าทำไม เพราะอะไร ถ้าเค้าอยากรู้เราก็ให้เค้า
หาคำตอบดูว่าเป็นเพราะอะไร ให้เค้าไปทดลองหาคำตอบดูแล้วมาเล่าให้เราฟัง เพราะบาง
ที่เราก็ไม่รู้หรอก แต่เราไม่บอกหรอกนะว่าเราไม่รู้เราก็ให้เค้าไปหาแล้วเราก็เรียนไปกับเค้า
Thai flute makes sound in different pitches. If students want to know
about how the flute works, I will encourage them to explore and find the
answers on their own. Then, I will ask them to share what they find with
the class. We [teachers] cannot know everything. Some questions that
students ask me, I don't know, too. But, I won't tell them I don't know the
answer. I will let them find out and then I will learn from them. (Wanna,
Card Sort Activity)

PCK for Primary Science Teaching

Knowledge of students' understanding of science. Wanna indicated that in order to help students understand science concepts, such as states of matter, she would allow students to do an activity to have some ideas about the concepts. Then, she would encourage students, as a whole class, to develop an explanation and conclusion about each activity. Wanna indicated that she might provide some information for students when she found that students got confused with their ideas.

สมัยนี้ครูควรจะเป็นผู้กำกับไม่ควรเป็นผู้แสดง ควรให้เขาลองทำลองคิดลองถูกเราคอยดู คอยแนะนำ เวลาเขาถามก็ไม่ควรจะต้องตอบ ส่วนมากเวลาเค้าถามก็จะบอกอย่ากรู้อีกก็ลองทำดูซิ ถ้าเราตอบเขาไม่ค่อยสนใจผ่านไปเลย บางทีเราไม่ตอบเขาก็อย่ากรู้อีกเขาก็ลองทำ

The teacher should be a facilitator rather than the director. We should provide opportunities for students to try out things on their own. They might have many curiosities and brings several questions, but we should not answer them. I will tell my students if they want to know, they have to find it out. (Wanna, Interview #1)

In regards to students' prerequisite knowledge, Wanna indicated that students did not know anything when they came to classroom. Wanna stated that, in general, students would understand science concepts only when they came to class. Wanna demonstrated that students did not have any ideas about science concepts, such as state of matter, before they came to the classroom, unless they took extra tutorial program outside school. Wanna indicated that if students read a textbook before coming to class, which hardly ever occurred, they might develop some understanding about the topic that they were going to study.

บางทีจากที่สอนบางคนก็ไม่รู้ แต่พอมาเรียนแล้วถึงจะรู้ว่า เออของแข็งทำไมรูปร่างมันถึงได้คงที่ ของเหลวทำไมรูปร่างมันถึงไม่เปลี่ยนไป บางทีบางคนก็ไม่รู้คนที่เก่ง ๆ บางทีเขาก็มีประสบการณ์ไปเรียนพิเศษมาก่อน อ่านล่วงหน้ามาก่อนบางคนขยันก็พอจะรู้ แต่ว่าธรรมดาๆ ไม่เรียนก็ไม่อ่านก็ไม่รู้ รู้จากที่ในห้องนั้นแหละ มีหลายรูปแบบ บางคนเด็กที่ไปเรียนมีความรู้มากสามารถจะมาบอกเพื่อนถ่ายทอดเพื่อนได้เขาไปเรียนพิเศษข้างนอกกัน อย่งอย่างครวหน้าจะขึ้นเรื่องของแข็งก็ลองถามดูเกี่ยวกับให้เขาอ่านมงกฎทองคำ เขาไปอ่านมาล่วงหน้าเขาบอกได้หมดเลยว่าจะหาปริมาตรอะไรยังไง เขาไปอ่านมาก่อน

Students don't know it except they learn from somewhere. Some students learn from the tutorial class so they might know about properties of

matter. So, these students may share with their peers before class. Or if I assign students to read before coming to class, they will have ideas about this concept. But, in general, students don't know it until they study in classroom. (Wanna, Interview #1)

The excerpt above reveals that Wanna did not demonstrate an understanding that students commonly had knowledge that helped them to make sense of the world around them and they usually brought that knowledge to class whether or not they had studied about that topic before. Wanna's unawareness concerning students' prior knowledge also became apparent during the card sort activity. Wanna did not agree with the teaching strategy in scenario 1 of having students draw a picture of sugar in water. Similar to most teachers, Wanna indicated that she would prefer students to have real experience of this phenomenon instead of having them to draw a picture.

เมื่อน้ำตาลสามารถที่จะหามาให้เด็กได้ลองละลายกับน้ำได้ ก็ให้เค้าละลายน้ำเลยดีกว่าจะมาให้วาดรูป

We can find sugar and water for students to perform this activity. So, it is not necessary to have them draw a picture. (Wanna, Card Sort Activity)

In addition, it is evident that Wanna did not realize about the students' difficulties in learning the concept of states of matter. As she indicated in the excerpt below:

คิดว่าไม่ยากเขาจะสนุกด้วยเพราะว่ามันเกี่ยวข้องกับเขา การทดลองก็ง่าย ๆ พื้นฐานของแข็งก็มีการหาความหนาแน่น ก็คิดว่าไม่ยากเท่าไรคือเอามวลให้ซึ่งมวลแล้วก็หาปริมาตร เด็กเขาก็พอจะเป็นก็เอามาหารกันก็คือความหนาแน่น คิดว่าไม่ยากเท่าไรที่ถามๆ ดูนักเรียนหนึ่งชั่วโมงที่ผ่านมาให้นักเรียนอ่านมาก่อนก่อนจะขึ้นเรื่องใหม่ลองถาม ๆ ดูเขาก็เข้าใจกันจะสอนเราก็เอาเครื่องมือมาแนะนำให้เขา เรื่องนี้เราจะเริ่มทดลองแล้วก็ให้เขาจัดอุปกรณ์ Beaker หลอดทดลอง ถ้วยยูเรก้าอะไรอย่างนี้ก็ให้เขารู้ใช้ยังไง การใช้ตะเกียง การจุดตะเกียงพื้นฐานก็สอนเขาก่อนที่มีการทดลองตอนแรกยังไม่รู้จักเพราะเรายังไม่ได้ใช้ พอหน่วยนี้เริ่มใช้ก็ต้องให้เขารู้จักเครื่องมือก่อนเขาก็มีพื้นฐานในการใช้ถ้วยยูเรก้าว่าใช้หาปริมาตร เค้าไม่เคยใช้ คือเขาเห็นในห้องวิทย์เอามาให้เขาดู เขาบอกคุณครูใช้ทำอะไรก็บอกเค้าทดลองไปดูในหนังสือซี ในหนังสือมี เขาก็ไปอ่าน

I think this topic [properties of matter] is not difficult for students. I think students will have fun with the activities. For example, when learning about the concept of density students can find the mass of an object and its volume. Then they can calculate the density of that object. They are also excited with the materials, such as eureka cup or alcohol lamp. Students already know how to use eureka cup so I don't think they will have problems with this activity. They may have questions about some

materials that they have never used. But, I will help them to find that in an activity book. (Wanna, Interview #1)

Wanna demonstrated that she did not know the common misconceptions of properties of matter that had been identified by the educators or researchers. This could lead to confusion about using instructional strategies and/or activities that helped to interpret students' actions and thought.

Knowledge of science teaching strategies. Based on Wanna's reflection of the card sort scenarios, she believed that in teaching science teachers should provide opportunities for students to do activities, analyze results to reach answers for questions, and make decisions and conclusions of the activity based on reasonable use of data.

ให้เขาได้ทดลองเองได้มาอธิบายจากสิ่งที่เขาเห็นข้อมูลหรือจากตารางบันทึกให้เขาได้มีส่วนร่วมได้เป็นผู้สรุปเองจากผลการทดลองให้เขาได้คิดว่าทำถึงได้เป็นอย่างไรให้เขาให้เหตุผลมา

I will let them do the activity and discuss after that by using data that they have. I will get them involved by allowing them to express their thinking about each activity or phenomenon. (Wanna, Interview #1)

However, during the card sort activity, Wanna indicated that she would make sure that students really understand how to do the activity. Thus, she would provide activity directions for students before allowing them to do the exploration.

เวลาทำการทดลองเราจะมีอธิบายว่าต้องทำยังไง เราก็จะมีตารางบันทึกให้บ้าง บางครั้งเราก็จะมีใบงาน เราต้องบอกเด็กก่อนว่าจะต้องทำอะไรยังไงเป็นลำดับขั้นตอน ไม่อย่างนั้นเค้าก็ทำไม่ถูก

Before students do the activity, I will explain to them what and how to do the activity. Sometime I give them the observation sheet to record their data. I need to clearly explain the direction in steps, otherwise they cannot perform it correctly. (Wanna, Card Sort Activity)

Wanna's teaching strategy stated during the card sort activity was apparent when she taught the concept of properties of gas to students. The teaching strategies that Wanna used were different from those used on the days that she taught concept of properties of liquid. Wanna provided activity directions to students and dictated to students the

expected activity results. Hence, it could be said that although Wanna displayed knowledge about how science should be taught, her teaching strategies were inconsistent depending on what topic that was being taught and the timeframe.

In addition, although Wanna used many ways of representing in order to facilitate students' learning, there was not enough information to develop claims that what she knows about the specific strategies, activities, and analogies helped students to comprehend the concept of states of matter. For example, when asking Wanna about the joss stick activity, Wanna only indicated that this activity helped students to see that gas could spread into the container.

ยกตัวอย่างของแข็งของเหลวหรือแก๊สนี้ ทำไมมันถึงรูปร่างไม่เหมือนกัน เด็กก็จ้ะรู้เพราะอะไร จากที่ว่ายกตัวอย่างให้ดู หรืออย่างอากาศหรือแก๊สนี้ รูปร่างเป็นยังงใดก็ไม่เคยเห็น แต่พอเค้าได้ทดลองเค้าก็จ้ะรู้่อ ที่เราจ้ดรูปให้ดู เค้าก็จ้ะรู้่ออากาศรูปร่างมันเป็นงใด เพราะยังเค้าไมจ้รูรูปร่างเป็นงใด ก็ยกตัวอย่างให้ดูเค้าก็เข้าใจ
Gas is difficult to see. For example, we cannot see air. I put smoke into a bottle because I want my students to see that gas can spread all over the container. After I did this activity, students understood about the property of gas in terms of changing shapes. (Wanna, Interview #2)

However, she did not understand the strengths and weaknesses of this activity in terms of developing students' understanding of this concept. Wanna also did not demonstrate the awareness that the activities and analogies she used might develop misconceptions among students. For example, Wanna did not display her understanding that using the *holding hand* model to represent the molecules of matter in each state might lead students to misunderstand about characteristics of atoms and molecules.

อย่างของแข็งให้เขาจับมือกันแบบว่าเกาะติดกัน สถานะของแข็ง ของเหลว แก๊ส ให้เขาเห็น ว่ารูปร่างถ้าของแข็งนี้โมเลกุลมันจะยึดเกาะกันแน่นจะให้เขากอดกันคล้ายกับว่าของแข็งรูปร่างมันจะคงที่ไม่ว่าจะให้เขาเดินตรงไหนมันก็ยังเหมือนเดิม แต่ว่าของเหลวให้เขาจับมือห่างๆ กัน ให้เค้าเดินไปมันก็จะเป็ไปเป็มาส่วนแก๊สก็ให้เค้าอยู่คนละทิศคนละทาง แล้วก็ให้เค้าเปรียบเทียบกับสถานะของของแข็ง ของเหลว แก๊สนี้มันจะเป็นแบบว่าของแข็งรูปร่างมันจะคงที่เพราะว่าโมเลกุลของมันเหมือนกับที่ตัวเราเกาะกันแน่นเลย ส่วนของเหลวรูปร่างมันไม่แน่นอนเพราะว่าโมเลกุลของมันเหมือนกับที่เราจับมือกันห่างๆ กันแรงยึดเหนี่ยวระหว่างโมเลกุลมันน้อยมันก็เปลี่ยนแปลงรูปร่างได้ ส่วนแก๊สนี้มันอยู่คนละที่มันก็จะฟุ้งกระจาย รูปร่าง

ไม่แน่นอน ก็เหมือนกับนักเรียนอยู่ห่างๆ กัน ก็คือให้เขาเปรียบเทียบ ถ้าพูดถึงโมเลกุลอย่าง เดียวนี้เขานึกไม่ออก เปรียบเทียบสถานะของแข็ง ของเหลว แก๊ส

I will have students hold hands very tight to represent molecules of matter in solid state. I will ask them to move around to see that how difficult the movement occurs. This represents that why a solid has a constant shape. Then, I will ask students loosen their hands and move in order to refer to the matter in the liquid state. Finally, I will have students release their hands and see how easy they can move. This analogy represents the matter in gas state. Then, I will discuss with students about the properties of matter in each state. If we only instruct them to know the molecule, they could not understand it. But, this analogy helps them to picture how the molecules of solid, liquid and gas look. (Wanna, Interview #2)

Knowledge of science curriculum. Wanna indicated that, in regards to the reformed science standards, students should have opportunity to get involved in learning as much as possible. For example, rather than telling everything to students, teachers should encourage students to respond to their own learning, such as developing their own explanations in order to sharpen their thinking skills.

เด็กได้เรียนจากประสบการณ์จริง มันก็ถูก มันก็ดี ครูต้องเปลี่ยนตัวเองด้วยไม่ใช่ว่าจะต้องคอยบอกตลอด คือเขาเคยชินกับการว่าครูต้องบอก ครูเองก็ชิน เด็กบางทีถามอะไรคิดไม่เป็นจะรอแต่ครูบอกอย่างเดียวยังคิดไม่เป็นก็พยายามฝึกให้เขาคิดอย่างเวลาสรุปผลการทดลองเราก็พยายามให้เขาได้มีส่วนร่วม สมัยนี้ครูควรจะเป็นผู้กำกับไม่ควรเป็นผู้แสดง ควรให้เขาลองทำลองผิดลองถูกเราคอยดูคอยแนะนำ เวลาเขาถามก็ไม่ควรจะต้องตอบ ส่วนมากเวลาเค้าถามก็จะบอกอย่างรู้ก็ลองทำดูซิ ถ้าเราตอบเขาไม่คอยสนใจผ่านไปเลย บางทีเราไม่ตอบเขาก็อยากให้เราลองทำให้เขาได้ทดลองเองได้มาอธิบายจากสิ่งที่เขาเห็นข้อมูลหรือจากตารางบันทึกให้เขาได้มีส่วนร่วมได้เป็นผู้สรุปเองจากผลการทดลองให้เขาได้คิดว่าทำถึงได้เป็นอย่างนี้ให้เขาให้เหตุผลมา เขาก็มีความภูมิใจ พอครั้งต่อไปเขาก็จะพยายามจะตอบพยายามสรุปเองในการทดลองอันนั้น อะไรอย่างนี้ ก็รู้สึกว่าเขาชอบ

It is good that students have opportunities to learn from their experiences. Teachers have to change the roles from telling everything to letting students try things out on their own first. When students do the activities, they will see what happens and can explain and make conclusions based on their observation. They will be proud of themselves when they are able to do it. I think they like this way. (Wanna, Interview #1)

Also, Wanna indicated that the new science curriculum contained more content knowledge that students needed to learn than the previous curriculum.

มันได้เรียนเยอะขึ้น เนื้อหามันเยอะขึ้นตอนนั้นมันเกี่ยวกับสังคม สุขศึกษา วิทยาศาสตร์ 3 วิชา เนื้อหามันก็น้อยลงแต่พอมายแยกเป็นเอกเทศแล้วเนื้อหาแต่ละอย่างมันก็ลงลึกขึ้นละเอียดขึ้นก็ดี

Students learn more content when we used this curriculum. Science content in the previous curriculum was superficial because it had to share with other two disciplines, including social studies and health education. (Wanna, Interview #1)

Wanna believed that the new curriculum provided information and knowledge about each concept in more detail, which she really liked.

Knowledge of assessment of scientific literacy. Similar to other teachers, Wanna indicated that she adopted many assessment instruments in order to assess students' understanding of science and performance of doing science laboratories. In addition to the common formative and summative assessments, such as asking questions, assigning worksheets, and testing, Wanna also used performance assessment in order to assess students' ability in doing laboratories.

ดูจากเวลาเราถามเขาจะแย่งกันตอบ เราก็มีคะแนน กลุ่มนี้ตอบได้จะให้คะแนน เขาจะแย่งกันตอบ ตอบไม่ถูก ก็มีการสอบ อย่างนี้ก็ตั้งใจจะสอบเก็บคะแนนไปเลยที่เรียนจะสอบเป็นคะแนนเก็บไปเลยเวลาทดลอง กะว่าจะเอาเรื่องนี้เก็บคะแนนไป เวลาอย่างเรียนเวลาทดลอง ถ้าเวลามันพอก็จะให้เขาออกมาทดลอง ส่วนมากจะเป็นเทอม 2 เพราะได้ทดลองมาเยอะแล้ว เค้าจะจับสลากให้เขาทดลองเรื่องนี้เขาจะต้องเตรียมอุปกรณ์อะไรมาบ้าง ส่วนมากจะเป็นเทอม 2 เพราะทดลองมามากแล้ว แล้วหาว่าทำการทดลองยังไง ดำเนินการยังไงและจะสรุปอย่างไรให้เตรียมตัวมาอาทิตย์นึง เราเอาชื่อเรื่องให้เขา เช่น เรื่องแรงดันอากาศเขาจะใช้อะไร เพราะมันมีได้หลายอย่าง เขาจะเลือกเอาแบบไหนล่ะเราก็ทำให้เขาดูหลาย ๆ อย่างแล้วเวลาสอบเขาจะเลือกเอาว่าชอบวิธีไหน เขาก็จะทำกันได้ดี เป็นที่สนุกสนานกัน เกร็งเครียด

I will assess them from their participation in the classroom. I also assess their laboratory ability by giving them choices of activities. Then, they have to draw what activity they need to study and prepare. I will give them one week to prepare about the activity. It might be pressure to them, but they seemed to like it, too. (Wanna, Interview #2)

Students had to participate in this assessment in the second school term. Wanna would give choices of experiments for students to select and prepare to complete in class.

According to the performance assessment on laboratory skills, Wanna would score students on their ability in using the scientific materials.

Although Wanna used many types of assessment instruments, she did not demonstrate knowledge about what important aspects of the concept of states of matter

that students should understand and how those important aspects could be assessed with the assessment instruments she used. In addition, Wanna did not exhibit her knowledge about the advantages and disadvantages of using these instruments associated with students' learning.

In summary, Wanna displayed that she had limited knowledge of students' understanding of science and science teaching strategies. Wanna did not show her understanding concerning students' difficulties with learning the concepts she taught. In addition, she did not know the common misconceptions about the properties of matter and atoms and molecules among elementary students. Hence, the limitation of knowing students' knowledge of science led to her ignorance in eliciting students' ideas before teaching. In addition, Wanna also demonstrated that she did not know the weakness of her analogy used to students in order to explain about molecules of matter in each state. Finally, there were not enough evidence to develop claims about to what degree she understood curriculum and assessment. However, the interviews with Wanna showed that she did not explicitly demonstrate her knowledge about the strength and weakness of each assessment instrument that she used with students.

The Cross-Case Analysis of Primary Teachers' Implementation, Orientations, and PCK for Primary Science Teaching

Observing the classroom teaching of four professional development participants through the entire PD topic series that they taught revealed that the teachers filled the role of information provider and there was very little input by their students. Encouraging students to talk during science lessons generally occurred at the beginning and at the end of the lesson when the teachers asked some questions. This teaching practice revealed

that the teachers believed science to be factual knowledge that could be discovered and that science instruction helped the learners understand this body of knowledge through activities and teachers' explanations. None of the teachers appeared to take students' ideas and experiences seriously. The teachers did not seem to have knowledge about students' learning difficulties or prior knowledge before the students came to the science classroom. The teachers explained that students did not have any difficulties understanding the concepts when they left the science classroom because the students could develop an understanding of the concepts by doing activities, listening to teachers' explanation of the scientific knowledge, and providing verbal and written answers to questions.

Many teachers provided hands-on activities to students without knowing why or how those activities were relevant to the particular concept they were teaching. Observing classroom teaching also revealed that there was little opportunity for students to conduct their own learning and discussion. Most of the time, communication during science lessons was unidirectional, with students being passive recipients of information. In addition, the teachers' questions, discussions, and teaching strategies did not seem to develop conceptual understanding of the concepts under study. The questions asked in the classrooms were close-ended and subject-centered and did not prompt students' critical thinking, but instead led toward factual knowledge.

Observations also revealed that the limitation of content knowledge in the topics that teachers taught was an important factor that influenced their decisions during instruction. For example, Manee and Chujai decided to direct their students to the right answers by asking leading questions or directly giving the answers. Jinda struggled with

unexpected activity results, which came from her modification of a sound activity. Rather than challenging students to discuss the unexpected outcomes, Jinda decided to skip this part and encouraged her students to try this activity again at home. In regards to Wanna’s case, although she seemed to provide more opportunities for students to discuss and share their ideas than the other teachers, she decided to stop students’ questions when she realized that she would not be able to answer those questions. Instead, Wanna provided unclear answers that could develop student misconceptions. The teachers’ orientations to science teaching and other knowledge bases for teaching science are discussed in the following assertions.

Assertion 1: The Professional Development Participants Displayed Didactic and Activity-Driven Orientations in Teaching Particular Science Concepts. These Orientations Deviated from the Science Education Standards, but were Similar to the Professional Developers’ Orientations.

During science teaching, the teachers attempted to teach particular topics through inquiry using the 5E model of instruction approach. However, the orientations teachers displayed were more toward the didactic orientation rather than the inquiry or guided-inquiry orientations. Table 16 shows the orientations for science teaching that each teacher displayed.

Table 16

Orientations of the Individual Professional Development Participants

Participants	Orientations
Manee	Didactic, and Activity-driven
Chujai	Didactic
Jinda	Activity-driven, and Academic Rigor
Wanna	Academic Rigor and Discovery

During the interviews and card sort activities, the teachers referred to science as a collection of factual knowledge. It appeared that they directed students through activities, discussions, lectures, and questioning so that the students would respond with answers that the teachers expected to hear. The teachers also mentioned that the activities that they provided to students only had one right answer. During the activities, the teachers instructed students to repeat the activity when the students found outcomes that were unlike the answers in their textbook. Although many teacher participants displayed a didactic orientation in terms of directing students toward understand the scientific content knowledge, their teaching approaches were different from each other. For example, in Manee's classroom, students had the opportunity to participate in a hands-on activity following Manee's directions. She provided step-by-step instructions for students and wrote the activity results and conclusion on the board at the end of each activity.

อยากให้เขาฟังเราเวลาจะทำการทดลองอยากให้เขาฟังขั้นตอนของเราให้ถูกต้องก่อนบางคนไม่สนใจ บางคนก็เล่น เล่นผิดจุดประสงค์ทำการทดลองผิดเราอยากให้เขาทำการทดลองแล้วได้ความรู้ให้มากที่สุด อยากให้เป็นอย่างนั้น

I want them to listen to me carefully so they can do the activity correctly. Some students don't pay attention on my explanation which leads them do the activity wrong. Some students do not follow the directions so their results do not meet with the activity's goals. When I have them do activity, I want them to learn as much as they can. (Manee, Interview #2)

During the activity, Manee informed students who had unexpected results to repeat the activity. In the discussion step, Manee asked close-ended questions to lead students to the right answer according to the textbook. When she found that some students did not have the correct answer, she directly told them that their answer was incorrect and told the students to write the correct statement on the observation sheet. It also appeared that Manee relied heavily on the teacher guide-book. She read the conclusion and results

statement in the guide-book directly to the students in order to have students write that statement down in the activity sheet.

In Wanna's classroom, students had more opportunities than Manee's students to discuss and share their ideas. However, Wanna still directed students toward the factual knowledge at the end of the activity looking at the properties of gas. According to Chujai, she believed that science concepts and theories are unchangeable. So, students should have accurate knowledge on those concepts.

บางกิจกรรมเราต้องมาถามว่าคนนี่ตอบว่าไงๆ แล้วมาสรุป เพราะบางเรื่องถ้าเขาไม่มีความเข้าใจตรงกัน คุณไปคิดเอาเองฉันสอนไปแล้วเด็กก็จะเข้าใจผิดไปเรื่อยๆ ถ้าหากว่าหัวข้อนั้นไม่สมควรให้เด็กคิดเองเพราะว่าเขามีกฎตายตัวอยู่แล้วคุณจะไปแหกกฎเขาเราก็ควรจะสอนในสิ่งที่ถูกต้องและสรุปให้ตรงกันทั้งห้อง แต่บางเรื่องก็ให้เขา คิดเองว่าจะเป็นอย่าง
บ้าง

Some activities, I have to make conclusions for them to ensure that every student understands the same things. If we let the students think on themselves without our help, they may hold a misunderstanding.

Especially, if it is law or theory, they need to understand it correctly and cannot think differently to that. Thus, as teachers, we need to give correct knowledge to students. But, if it is a simple concept, I will let them think on their own. (Chujai, Interview #2)

In addition to the didactic orientation, some teachers also displayed other orientations to science teaching such as: activity-driven and academic rigor. In regards to the activity-driven orientation, none of the teachers used hands-on activities as a tool to promote conceptual thinking among students. Rather, it appeared that their utilization of hands-on activities in science classroom was solely for verifying and discovering science concepts. The orientation of teachers also led them to develop a teacher-centered and knowledge-centered learning environment rather than a student-centered learning community. The teachers did not provide an opportunity for students to design their own activities to investigate phenomena based on their interests. Instead, the teachers typically gave the students manipulative kits that were designed by the curriculum developers and

instructed students to follow the activity directions in the curriculum and then instructed students about that concept. Many times the teachers demonstrated that they did not conceptually understand the purpose of activity that was provided for students. Hence, it appeared that the teachers inappropriately implemented the activity with their students and failed to help students develop understanding of the teaching topics. For example,

กิจกรรมนี้มีข้อบกพร่องหลายๆ อย่าง ความรู้สึกเด็กไม่เท่ากัน การจับเวลา คือเรา control ไม่ได้ บางที่เราบอกเริ่มจับเวลาเนะ บางคนยังเล่นอยู่เลยเด็กเข้าใจไม่ตรงกัน และเรา control เรื่องเวลาไม่ได้ เรื่องความรู้สึกเด็กว่าอันไหนมันร้อนก็วิ๊ ๆ แต่ละกลุ่มจับก็จะไม่เหมือนกัน ทั้งที่เราบอกเริ่มต้นแล้วนะ ถ้าถามว่าจะไม่เอากิจกรรมนี้เลยไหมมันก็มีประโยชน์อยู่บ้างความรู้ก็ยังมีอยู่บ้าง แต่ว่ามันไม่เด่นชัด ยอมรับเลยว่ากิจกรรมนี้เด็กงงๆ เห็นชัดเลยสุดท้ายเราก็พยายามอธิบายเค้าว่าการนำความร้อนมาคืออะไร นำไปใช้ประโยชน์อะไรบ้าง เขาก็มีคำถามเยอะแยะมากมาย เพราะฉะนั้นเราต้องศึกษาค้นคว้าบางที่คำถามบางคำถามเราคิดไม่ถึงด้วยซ้ำไปมันทำมาจากอะไร ถ้าทำแบบนี้แล้วได้แบบนี้ ถ้าหากเราไม่รู้แน่ชัดคำตอบนี้ครูขอติตไว้ก่อนเดี๋ยวครูไปหาคำตอบให้เพราะว่าบางที่ถ้าคำตอบตรง ถ้าเราพูดไปแล้วความรู้เราไม่แน่นเด็กอาจจะเข้าใจผิดก็เลยต้องคำตอบนี้ติตไว้ก่อนแล้วไปบอกเขาทีหลัง เขาก็เข้าใจ

This activity is not perfect because students' feeling are varied. Another problem is timing. I cannot control anything when students are doing this activity. During the activity, students don't understand the same things in terms of what they have to do. While their peers are doing the activity, some students play and don't have attention to the activity even though I called them several times. In my opinion, this activity is not clear. At the end of the activity, I noticed that students were still confused with it. Finally I have to provide knowledge to them about the concept of conduction of heat and how this knowledge is useful for their life. Students always have a lot of questions that many times I don't expect those types of questions. So, I have to tell them that I will find the answer and tell them later. Sometimes if we don't have solid knowledge, we may give them wrong answers and lead them to have misunderstandings about that concept. (Chujai, Interview #2)

This excerpt from Chujai provides an example of how the didactic and activity-driven orientations fit together. Chujai chose an activity because she wanted her students to understand that different types of spoons conduct heat differently. She attempted to use the results of this activity to demonstrate to students why people have hot soup using a spoon made of stainless steel. However, this activity was not as conceptually coherent to students as she anticipated. In addition to her limited knowledge about the concept of

heat conduction, this particular activity, and pedagogy, Chujai ignored the confusion of her students and provided a direct explanation about heat conduction and its application.

In Wanna's case, it is evident that she also displayed an academic rigor orientation when she taught about the properties of matter. She challenged students with a problem to verify the students' understanding of the properties of a liquid and the relationship of this concept to phenomena around them. Wanna provided an opportunity for the class to discuss the topic. However, her limited content knowledge on the topic constrained her teaching.

In summary, it appeared that during science instruction, teachers displayed multiple orientations when they taught a particular topic. The multiple orientations that teachers held, such as didactic and activity-driven orientations, seemed to fit well in the science classroom. For example, teachers directed students through hands-on activities in order to guide students to observe the expected results stated in the curriculum. The teachers did not seem to recognize whether or not the activities would facilitate students understanding because they would instruct students again after they finished the activities. Furthermore, it is evident that the teachers' orientations to teaching science were not consistent dependent upon the topics that they were going to teach.

Considering the Orientations of Professional Development Participants in Light of the Professional Developers' Orientations and the Reformed Science Education Standards

The activity-driven orientation of the PD participants influenced their science instruction as evident by when they provided hands-on activities to students and explained the science content after the activities. This teaching approach was similar to the professional developers' teaching in the PD when the professional developers

emphasized providing hands-on experiences that were similar to the classroom activities before providing the teachers the correct explanations of each activity. Both professional developers and teachers, as instructors, seemed to use hands-on activity as a tool to engage learners in learning science facts rather than for understanding science concepts.

Similar to the professional developers, the activity-driven orientation that the teachers displayed fit with the reformed Science Education Standards with respect to the standards requesting teachers to provide opportunities for students to participate in science activities. Thus, the teachers tried to use questions in order to initiate students' curiosity and attention to learn science. Teachers also encouraged students to perform hands-on activities that were in the curriculum.

Although the PD participants provided opportunities for students to perform science activities, the purpose for this learning event was different than the purpose stated in the standards. The standards indicate that teachers should allow students to investigate phenomena and activities in order to facilitate students developing meaningful understanding of the phenomena. However, the teachers used hands-on activities with students in order to attract students' interest and verify the knowledge that was shown in the textbook.

กระบวนการเรียนที่ผู้เรียนจะต้องสืบค้น เสาะหา สืบตรวจสอบ และค้นคว้าด้วยวิธีการต่างๆ จะทำให้ผู้เรียนเกิดความเข้าใจและเกิดการรับรู้ความรู้นั้นอย่างมีความหมาย
The learning process is a process that learners have to investigate and research for information through various methods in order to develop meaningful knowledge (Standards, p. 219).

ชอบสอนเรื่องแรง เพราะว่าเรื่องแรงมันมีกิจกรรมให้เด็กทำ ค่อนข้างเยอะแล้วเด็กเค้าชอบ เขาจะสนุกเรื่องอะไรก็ตามที่เค้ามีการทดลองค่ะ เขาจะชอบเหมือนกับเขาได้ทำกิจกรรมกับเพื่อน ๆ แต่ถ้าเป็นเรื่องที่เป็นเนื้อหาโดยตรงทางชีวะอะไรอย่างนี้ เด็กเขาก็จะเบื่อแต่ถ้าได้ลงไป อย่างสอนเรื่องส่วนประกอบของดอกไม้พาลงไปดูของจริง เขาก็จะชอบ ให้เค้าเอามาเองนี่ เขาก็จะสนใจ แต่ถ้ากลับกันให้สอนตามเนื้อหา ตามหนังสือเด็กเขาก็เบื่อยิ่งสอนตอนบ่ายๆ ยิ่งง่วงหลับไปเลย คือกิจกรรมไหนถ้าเด็กสนุกเราก็ชอบ

I like to teach concepts of force because there are many fun activities in this unit. Students will enjoy doing activities because it is like playing with their friends. If we teach them through rote learning, they will get bored. Especially they look sleepy when science class is in the afternoon. But, if we have some activities for them to play, they will get excited. I like to teach science when there are activities that students will enjoy. (Manee, Interview #1)

ทดลองของแข็งไปแล้ว เรากล่าวว่าของแข็งมีมวลไหม เด็กบอกว่าของแข็งไม่มีมวล ที่ถ้วยยูริกาที่คุณทำไปเมื่อกี้นี้จะบอกของแข็งไม่มีมวลได้อย่างไร เอ้าเราก็เริ่มใหม่เอาใส่บีกเกอร์ใสเลย น้ำล้นออกมา ตกลงของแข็งมีมวลมั้ยะ มีละ นั้นแหละเด้าจะเริ่มได้ละ
I ask them after they did activity on properties of solid whether solid matter has mass. They said no. They cannot relate the activity of putting play-do in eureka cup. So, I started doing this activity again and when some water came out from the eureka cup after putting in the play-do, I asked them again about solid matter containing mass or not. Then, students started to know it. (Manee, Interview #2)

ทำการทดลองครั้งแรกเด็กยังงงก็มาทำการทดลองอีกที แล้วก็มาสอนเนื้อหาเพิ่มมากขึ้น ครั้งแรกทำการทดลองเขายังไม่รู้แต่ครั้งที่ 2 เริ่ม get ขึ้นหน่อย พอพูดครั้งที่ 3 ก็รู้เรื่องกับเขาบ้าง ต้องพูดเยอะๆ
Students get confused when doing an activity for the first time. Then, I repeat the activity again and explain the content about it. Students demonstrate their knowing after doing the activity the second time. Then, I explain the content to them 2-3 times. The majority of students seem to increase understanding. (Chujai, Interview #2)

In comparing the perspective of the teachers about teaching science within the Science Education Standards, there were instances when the teachers deviated. The Standards indicate that sustainable learning occurs through a variation of learning processes, which include the inquiry process rather than telling by teachers. The standards require learners to be encouraged to develop their thinking process, ability to learn, investigative process, problem solving skills, and the ability to search for and create new knowledge.

The teaching/learning of science emphasizes the learner as the person doing the learning and discovering by him/herself so that process and knowledge are acquired from the pre-school years through education at tertiary level and post graduate level and even at the work place. (Standards, p. 4)

The didactic orientation that teachers exhibited could not fulfill science teaching and learning as requested in the Standards. It was evident that the teachers believed that knowledge is facts, which students could learn directly from teachers. Thus, many teachers acted as knowledge experts by transferring knowledge to students at the end of activities. The teachers directed students to do the hands-on activities in order to discover or verify existing knowledge. In addition, the teachers did not demonstrate their appreciation of students' prior knowledge and how this affects their learning of new knowledge. Hence, teachers failed to elicit students' knowledge before learning a particular topic. The standards suggest that teachers facilitate student learning by employing various teaching methods, such as inquiry. It is evident that the didactic orientation that teachers displayed did not fit with this perspective of the standards.

ดังนั้นการที่ผู้เรียนจะสร้างองค์ความรู้ใดจึงต้องผ่านกระบวนการเรียนรู้ที่หลากหลาย โดยเฉพาะอย่างยิ่งกระบวนการสืบเสาะหาความรู้ (inquiry process) Learners can construct knowledge through the investigation process called inquiry (Standards, p. 219).

During the interview, observations of classroom teaching, and the card sort activity, none of the teachers mentioned the inquiry teaching approach. In addition, teachers did not indicate an appreciation of teaching science through an inquiry process. The teachers explained that the learning cycle consisted of 3 steps including: engaging students in the topics that were taught, providing hands-on activities, and explaining correct science knowledge to students.

สมมุติในระดับประถมอย่างการทดลองหรือว่าการสอนของเราเราจะเน้นการทดลอง เน้นเรื่องเนื้อหาให้เด็กเข้าใจ ส่วนเรื่องการปฏิบัติ เด็กก็จะปฏิบัติเพียงแต่ที่เราอธิบายขั้นตอนการปฏิบัติให้เด็กปฏิบัติเอง เราก็ตรวจสอบดูความถูกต้องความเรียบร้อยของเด็กอย่างนั้น แต่ว่ากับเด็กเล็กเราจะปล่อยให้เด็กเขาทำเองไม่ได้จริงๆ การสาธิตกับเด็กมันจะดีมากกว่าถ้าเกี่ยวกับการทดลองที่อาจจะอันตรายได้ สาธิตเด็กอาจจะไม่ค่อยรู้เรื่องมากแต่เขาก็จะสนใจกิจกรรมควรจะให้ทำการทดลองเองไหม เพิ่มเนื้อหาที่เด็กก็จะปวดหัวแล้วคะ ไม่รับแล้ว คำรับได้ในเนื้อหาสำคัญที่เราบอให้ถ้าเราจะเอาเรื่องอื่นๆ ให้เด็กเล็กๆ ถ้าไม่เกี่ยวกับชีวิตเขา ไม่เกี่ยวกับความสนุกของเขา คุณจะพูดไปก็ไม่มีทาง กับเด็กเนี่ยบางที่เราต้องเป็นตัวตลกเป็นตัว joke แต่เท่าที่รู้สึกว่าเป็นเด็กเค้า happy

To teach science at the primary level, we will emphasize doing the activity and the teacher will explain knowledge to students to help them understand it correctly. Although students have opportunities to perform activities, the teacher needs to provide clear steps to them before having them start doing the activity. Some activities that might have danger for students, we should demonstrate the activity to them rather than having them perform it. Although students might not understand the demonstration, they will have attention to what the teacher is doing. I think at the primary level, if we give much content knowledge to students, they are not able to deal with it. If the content knowledge does not relate to their lives or is not fun, they won't learn it although we try to explain to them so many times. (Chujai, Interview #2)

มันเริ่มจากการที่เด็กเขาได้สังเกตพอเด็กเขาสังเกตอะไรหลาย ๆ อย่างมันเหมือนกับเขาเริ่มมีปัญหาอยากถาม อยากรู้ อยากทดลอง ทำการทดลองเสร็จมีการทบทวนความรู้ถ้าเขาตอบได้ก็แสดงว่าเค้าเข้าใจ หรือในแบบบันทึกกิจกรรมที่ของ สสวท.ก็มีการตอบคำถาม มีแบบทดสอบท้ายหน่วย เขาต้องสามารถตอบคำถามได้ จากนั้นครูมาทบทวนเนื้อหาให้ ต้องมีการทบทวนเนื้อหาเหมือนกับยาอีกครั้งหนึ่งอธิบายเขากลับอีกครั้งหนึ่งให้เขาเข้าใจมากยิ่งขึ้น Science teaching begins with making students have curiosity about some things. Then, they want to do the activity in order to know the answer. I provide a wrap-up opportunity to see if students are able to answer the questions; that means they have understanding. I also assign students to answer the questions after the activity directions in the curriculum. After that, I will explain content knowledge to students again in order to develop clear understanding. (Manee, Interview #2)

เวลาที่เขาทดลองเขาจะตื่นเต้นมากเลย อย่างตอนที่อากาศมันมีแรงดันจริงหรือให้เขาจุดไฟในแก้วพอไฟดับรับเอาลูกโป่งปิดมันก็จะยุบสวบลงไปทำไมมันเป็นอย่างนี้ คือเขาไม่รู้ว่าเพราะสาเหตุอะไรพอเขาทดลองแล้วเราก็จะอธิบายกับเขาเพราะอะไร ๆ Students will get excited when they do the activity. For example, when I have students do the activity about air pressure, they are very excited when I asked them to blow a candle in a glass and then cover with a balloon. When students see a balloon get into the glass, they are amazed with the results. They don't know how this phenomenon happens. So, I will explain to them at the end of the activity. (Wanna, Interview #1)

It was only during rare opportunities that teachers promoted students' learning through the processes stated in the Standards.

Assertion 2: The Professional Development Participants' PCK was Limited. Their PCK was Associated with their Orientations.

Knowledge of students' understanding of science. Teachers indicated that in order to help students develop science content knowledge, they had to provide correct

explanations about that topic to students. Teachers might direct students to do the hands-on activities either prior or after the instruction depending on the level of difficulty of the topic. For example, to teach the concepts of sound and heat conduction, the teachers might provide opportunities for students to explore the hands-on activities and then the teachers would give the correct explanation about these concepts at the end of the activities. However, teachers might provide instruction about the circuit and current prior to have students doing hands-on activities when they have to teach about electricity.

In addition, none of teachers believed that elementary school students could take responsibility for investigation without help from teachers.

ฉันนี้ให้สำรวจ แต่ออกแบบการทดลองเราไม่ได้ให้ทำ อาจจะเพราะว่าเรายังไม่มั่นใจในตัวเด็กว่าจะทำได้หรือเปล่า แค่ ป. 5 ก็เลยไม่ค่อยจะเห็นด้วย
I only have students investigate or do activities that I prepare for them. I don't have confidence that 5th grade students can design their own experiment. (Jinda, Card Sort Activity)

Teachers did not demonstrate knowledge about learning styles nor how ability levels might be different among individual students.

In regards to areas of student difficulties, the teachers did not display knowledge or beliefs that students might have difficulties learning science. The teachers believed that if they provided a clear explanation to their students, the students would be able to understand the scientific knowledge. In addition, some teachers, such as Chujai and Jinda, indicated that their goal for teaching science was to develop the relevance of science knowledge to students' daily lives. Thus, they preferred to develop an appreciation about science in terms of its application and ignore developing a meaningful understanding of the scientific concept.

อย่างเรื่องความถี่นี้ก็ค่อนข้างหนักไปเหมือนกัน แต่เราไม่ค่อย serious มากเท่าไรคือ
อยากรู้แค่ว่าเสียงเท่านั้นเป็นอันตราย เสียงมันดัง เรานั่นแค่ว่าหนอย่าไปอยู่ที่เสียงดัง จะ

ไม่ให้จำว่าดังเท่าไรถึงจะอันตราย ให้แค่ฟังแล้วเรารู้สึกรำคาญ อย่างนี้ก็อันตรายแล้ว เราไม่เน้นให้จำแต่เน้นที่เค้าใช้ในชีวิตประจำวัน

I think the concept on frequency is the most difficult in the sound unit. But, I don't seriously emphasize developing knowledge about this concept to students. I only want them to know the danger of sound when it is too loud. So, they can live safely. (Jinda, Interview #2)

In addition, none of the teachers demonstrated knowledge about common misconceptions that their students might have before or after science instruction. This limited knowledge about student learning and ability to learn science led to limited decisions about teaching strategies to teach particular science topics.

Knowledge of science teaching strategies. While the PD sometimes focused on helping teachers adopt the 5E model of instruction for teaching science at their classroom, there was no explicit instruction about the 5E model of instruction they were expected to use. As indicated earlier, the common teaching strategies that teachers explicitly used in their own learning cycle included only 3 steps: engagement, exploration, and explanation by teachers. In addition, it is evident that a lack of subject matter knowledge and pedagogical knowledge influenced the misuse of science teaching strategies. There were many times when teachers decided to directly tell students the correct answers or knowledge when they struggled or faced unexpected circumstances.

ส่วนมากจะยากกับการคุมเด็กมากกว่า เรื่องอุปกรณ์ เรื่องการสอนไม่ยากสำหรับตัวเรา แต่ว่ามันยากเหมือนกับว่าทำไมเด็กไม่ค่อยสนใจเลย มันเหมือนกับว่ายากสำหรับการคุมห้องมากกว่า ถ้าถามว่าเรื่องเนื้อหา เรื่องการทดลอง เราก็เตรียมไม่ยาก เราทำเองทำคนเดียวแต่ในขณะที่สอนในขณะที่คุณลงมือทำ เขาไม่เหมือนเรา เวลาเราทำเราทำคนเดียว แต่พอให้เด็กทำเขาก็จะอยากรู้อยากเห็นอะไรตามประสาเค้าก็จะเกิดความวุ่นวายขึ้นยากสำหรับเราที่จะทำให้เขาเข้าใจและเป็นระเบียบอย่างวันนั้นก็เห็นทั้งดูทั้งว่า แต่จริงๆ ถามว่าการทำกิจกรรมควรจะเงียบเลยไหม ก็ไม่ แต่ก็ไม่ถึงกับว่าไม่สนใจครูเลยส่วนมากจะเจอแบบนี้ บางที่เราต้องหยุดเค้า ดุเค้า ให้ฟังเราอธิบาย

It is difficult to control students. Teaching the concept is not difficult to me, but how to have students do the activity carefully and seriously is more difficult. Students are not similar to adults. When I do the activity, I pay attention to it. But, the students don't. They like to play and make a mess in classroom. I don't mean that the science classroom needs to be quiet, but I want students to listen to me. Some times I have to stop them

from the activity and explain the results to them instead. (Chujai, Interview #2).

The Thai Science Education Standards request that teachers use diverse teaching strategies to serve the needs of individual students.

In providing science instruction, teachers should make use of diverse learning strategies to respond to the needs, interests and learning methods of the learners. (Standards, p. 3)

However, to teach a particular science topic, teachers did not offer various representations to help students develop an understanding of the topic concept. Although some teachers, such as Manee, directed students to do many activities, they did not facilitate students in develop relationships between the activities and the phenomenon. In other cases, some teachers indicated that they might invent other representations, such as analogies or models, to help students understand the concept that was taught. For example, Chujai, Wanna, and Jinda indicated that they would have students touch their neck in order to develop the idea that vibration makes sound. Wanna also indicated that to teach students about the arrangement of molecules in liquid, solid, and gas states, she would use an analogy related to students holding their hands differently. However, the teachers did not indicate knowledge about the disadvantages and risks, including that models and analogies might cause student misconceptions about that concept being taught. For example, Wanna's analogy related to students holding hands might cause students to believe that atoms within a liquid are longer than atoms within solids and gasses; this analogy may represent that there was something physically connecting two atoms together.

Teachers displayed limited knowledge of the activities they used in the classroom. Teachers implemented hands-on activities that were in the IPST curriculum or in the PD

handbook with their students. However, it was evident that the teachers did not have enough knowledge about the activities or how these activities were supposed to help students comprehend the specific concepts or relationships. The observations revealed that the teachers had limited content knowledge of the topic they taught. This lack of content knowledge led to the misunderstanding of the activities. In addition, the poor content knowledge caused teachers to inappropriately modify critical components of the activities.

ทำไมเราได้แต่ใช้มือเคาะ ทำไมไม่ใช้อย่างอื่นดู ลองดูได้มัย เรายลองเป่า เราก็เอ๊ะ มันก็มีเสียงนี้ ลองให้เด็กลองเป่าดูสิ ซึ่งก่อนทำเราก็ลองเป่าดูนะซึ่งมันก็มีเสียงนะ เพียงแต่เด็กเค้าอาจจะยังสังเกตได้ไม่เก่งเท่ากับเราเท่าไร แล้วบางคนประหลาดเลยเป่าแบบเบาๆ แล้วบางคนเป่าแต่ละขวดด้วยแรงไม่เท่ากันมันก็เลยเกิดความแตกต่างกันอย่างเห็นได้ชัด
I wonder why we have to knock it only. Can we use other method to make sound? I know that when we blow at the top of bottle, it has sound. I did a pre-lab before having students do it, and it worked. So, I tried this new method with my students. (Jinda, Interview #2)

In addition, there might be relationships among teachers' appropriate use of activities, their teaching experience, and their PCK. For example, both Manee, who had a strong didactic orientation, and Wanna, who had academic rigor and discovery orientations, taught the concept of the states of matter to their students. The activities that they selected for their students were similar since they were in the IPST Curriculum. Classroom observation of these teachers revealed that there were differences between the teaching approaches of these two teachers. In addition, Manee and Jinda's teaching approaches were different when they taught the concepts of sound.

Teachers did not demonstrate their knowledge of variation of teaching approaches for understanding the specific science concepts. Hence, the teachers did not use a variety of representations to develop meaningful understanding to all students. Instead, they used the same teaching approach in teaching each science topic. In addition, the decision about

using teaching strategies was influenced by the teachers' beliefs about how science teaching might constrain their teaching practice. For example,

เราสามารถ control เด็กได้ เด็กเค้าตั้งใจที่จะเรียน ถ้าเค้าเซว่บเราสามารถที่จะทำให้เค้าเข้าสู่บทเรียนได้ เรายืนยันว่าคุณมาแบบไหนก็เถอะขั้นปราบคุณได้ ไม่กลัว ส่วนเรื่องสอนวิทยาศาสตร์ต้องตลกนี่บางที่เราไม่ใช่คนตลก มันก็เหมือนกับผีต บางที่เราก็อยากให้มันตลกอะนะ เรายังรู้ว่าสอนวิทยาศาสตร์มันต้องสนุกสนานนะ แต่ด้วยบุคลิกของเรา เรายังไม่ใช่ไฮเฮสซาปาร์ตี้อะนะ มันก็ค่อนข้าง ยากให้มันเป็นอย่างนั้นละ แต่บางที่มันก็ไม่ใช่เรา I can control students to pay attention to the activities or lessons whenever they are off track. I am confident to do that. However, I feel uncomfortable with the idea that teaching science needs to be fun. I am not that kind of person. So, sometimes when I try to make a joke with my students, I feel it is unnatural because it isn't my personality. (Jinda, Interview #2)

The excerpt above reveals that Jinda thought teaching science in the elementary levels had to be fun. The elementary teacher needs to be a playful person who has a lot of jokes to share with students. Jinda indicated that this personality was opposed to hers. Consequently, Jinda demonstrated her anxiety that students might not be happy when coming to her classroom.

Knowledge of science curriculum. All teachers indicated that the current science curriculum was different than the previous one since science was now included in the Life Experience subject. According to this new curriculum, teachers indicated that there were many hands-on activities and a lot of content knowledge that students needed to understand. Some teachers indicated that their knowledge about the new curriculum included an understanding that students would be involved in learning by doing activities and developing their own explanations while the teacher's role was to assist in facilitating this learning environment.

หลักสูตรใหม่เน้นให้เด็กได้เรียนจากประสบการณ์จริง ไม่ใช่ว่าครูจะต้องคอยบอกตลอด คือเขาเคยชินกับการว่าครูต้องบอก เด็กบางที่ถามอะไรคิดไม่เป็นจะรอแต่ครูบอกอย่างเดียวคิดไม่เป็นก็พยายามฝึกให้เขาคิดอย่างเวลาสรุปผลการทดลองเราก็พยายามให้เขาได้มีส่วนร่วม เอ้าคนนั้นไหนลงสรุปซิผิดถูกไม่เป็นไรบางที่ก็เอาของคนนี้มาผสมกับคนนี้อะไรอย่างนี้ เขาก็มีความรู้สึกว่าเขาพูดถูกครูเอาของเขาขึ้นบนกระดาน เขาก็มีความภูมิใจ พอครั้ง

ต่อไปเขาก็จะพยายามจะตอบพยายามสรุปเองในการทดลองอันนั้น อะไรอย่างนี้ ก็รู้สึกว่าเขาชอบ

The new curriculum focuses on students to have real experience. The teacher does not have to tell everything to students, but gets students involved in the learning by encouraging them to develop reasoning and create knowledge through investigation. I try to follow this new teaching process by encouraging students to share their thinking. I found that students are proud when the teacher recognizes their answer. So, they try to answer questions and make conclusions. I feel students enjoy learning this way. (Wanna, Interview #2)

In addition, teachers indicated that the new science curriculum contained many fun activities that were appropriate to students. However, the teachers indicated that they also looked for other exciting activities from other resources.

Knowledge of assessment of scientific literacy. The interviews and card sort activities with each of the teachers revealed that the teachers displayed limited knowledge about assessment in terms of knowing what important aspects of the particular concepts needed to be assessed. In addition, the teachers' questions during classroom instruction focused on asking students to recall factual knowledge rather than asking for their understanding of the concept.

All of the participant teachers indicated that they planned to use different methods of assessment during the school term. These methods included asking questions and observing students' responses during classroom teaching, looking at students' work and their participation in hands-on activities, concept mapping, and scores from multiple-choice and laboratory practical examinations. The teachers believed that using many assessment methods helped them generate a clearer understanding about how students understand the science content knowledge and that the use of multiple assessment methods was also fairer to students.

ก็มีใบงานให้นักเรียน ใช้วิธีสอบถามเพราะบางคนเขียนไม่เป็นถ่ายทอไม่เป็น แต่เค้าพูดได้ อย่างเด็กป. 4 เนี่ยบางทีเค้ายังเขียนหนังสือไม่ได้ เพราะฉะนั้นเราจะใช้วิธีแค่ทำข้อสอบ

ข้อเขียนนี้ไม่ได้ ต้องมีการ observe ขณะทำการทดลองเด็กสนใจมากแค่ไหน พอทดลองแล้วได้ผลถูกต้องมั้ย แล้วเด็กสนใจที่จะซักถามมั้ย คือมันต้องหลายๆ อย่าง สอบอย่างเดียวไม่ได้ เพราะเด็กบางคนไม่สามารถอธิบายเป็นการเขียน เหมือนกับให้เราเขียนเรียงความนะไม่เคยเขียนได้สักที เพราะฉะนั้นใช้วิธีสอบข้อเขียนอย่างเดียวคงเป็นการทำร้ายเค้า

In addition to the activity worksheet and examination, I use other assessment instruments with students because some students cannot well communicate well through writing, but verbalization. I also observe their intention in the classroom. I think this is fair to the students. (Jinda, Interview #2)

However, the use of assessment instruments by teachers focused on assessing students' knowledge of scientific facts more than other important aspects that teachers should monitor students during the learning process, such as students' alternative conceptual understanding.

Also, the teachers indicated that they knew many ways to assess students' science learning. However, there was not enough evidence to support claims about how much knowledge teachers had about each assessment method, why they decided to use these methods, and why these methods were more appropriate to use during a specified timeframe in order to assess a specific aspect of student learning rather than others. Observations of the use of assessment methods revealed that sometimes the teachers used the assessment instrument without knowing how to use the instrument appropriately. For example, Manee encouraged students to develop a concept map after they learned concepts about sound. The way in which Manee directed students to develop the concept map did not properly assess students' understanding about how vibrations make sound. Instead, Manee preferred students to make their maps beautiful rather than focusing on the thoughts and connections between concepts that the students developed.

Summary

This chapter reveals that the professional development participants displayed didactic and activity-driven orientations and two teachers, Wanna and Jinda, also

exhibited the academic rigor orientation. The individual teachers could exhibit more than one orientation when they taught a particular science concept. This orientation was either consistent or inconsistent when they taught different topics or lessons. In addition, the orientations that the teachers displayed deviated from the reformed Science Education Standards.

The professional development participants exhibited limited PCK, including knowledge of students' understanding of science, science teaching strategies, and assessment of scientific literacy. The teachers displayed moderate understanding about the curriculum they used. However, they exhibited poor knowledge of other three components of PCK. Similar to the case of professional developers, it is evident that the limitation of one type of knowledge resulted in the ineffective use of other types of PCK.

Coda

Reflections of the Professional Developers after Watching the Video Clips of Teachers' Teaching

After I finished collecting data with the teachers--Manee, Chujai, Jinda, and Wanna--I asked all professional developers to watch teaching video clips that I had made of the teachers. There was only one teacher, Wanna, who did not agree to be videotapes during her teaching. For Manee, she taught many science concepts including properties of liquids and gases, and sound. Thus, I did not have the professional developers watch every clips of Manee, but selected the video clip when she taught properties of liquids to her students.

When the professional developers watched all the video clips together as a group, I conducted a focus interview with them. According to the interview, the professional

developers looked surprised with the teachers' teaching. They realized that the teachers did not have strong content knowledge of the concepts that they taught. Piti discussed Jinda's modification of the activity from knocking to blowing at the bottle, recognizing that she did not have content knowledge of pitch, frequency, and resonance of sound.

เรื่องของการเป่าขวด มันได้ concept เรื่อง resonance ไม่ใช่เรื่องของน้ำมากแล้วสั้นๆ น้ำน้อยสั้นเร็ว มันไม่ใช่เพราะไปใช้การเป่า การเป่าเป็นเรื่องของ resonance แล้วก็ถ้าการเคาะถึงจะเป็นการสั้นแต่เด็กเค้าจะไม่เห็นการสั้น มันก็จะโยงไปถึงความถี่

When we blow at the bottle, it introduces the concept of resonance. I asked them to hit at the bottle to see how the water in each bottle waves differently. This can also lead to the concept of frequency. (Piti, Focus Group Interview)

Sommit, on the other hand, mentioned that teachers might not have strong content knowledge of the topics that they were video taped. However, the teachers might have good content knowledge of other concepts that I did not observe.

ตกลงทั้งของฟิสิกส์และของเคมีนั่นแหละ ครมึพื้นที่ความรู้ไม่แน่น ในเรื่องที่สอนนะ ในเรื่องที่เขามาให้ดู แต่เรื่องอื่นเค้าอาจจะเก่ง แต่ว่าเรื่องรอบตัว นอกนั้นก็ดี

We can see that in teaching the particular concept either physics or chemistry, teachers did not have good content knowledge. However, they might have good content knowledge in other concepts that we did not see the clips. And I think they have good teaching techniques. (Sommit, Focus Group Interview)

Somsri indicated that the video clip of teachers' teaching helped her to know that teachers from the private schools did not have good content knowledge just as teachers from the public schools. In addition, she realized that these teachers held misconceptions on the topics they taught.

ทำให้เรารู้ว่าครมึความไม่เข้าใจในเนื้อหาที่สอน concept มันไม่ค่อยได้ มี misconception ด้วย แต่เค้าไม่รู้ตัว เค้าถึงได้บอกที่เด็กจับประเด็นไม่ได้ ได้ดูอย่างนี้ก็ทำให้เรารู้ว่าต่อไปนี่เราจะมาคิดเองว่าครมึแล้วแล้วเราไม่หลงในรายละเอียดไม่ได้

These clips help me know that these teachers don't have good knowledge. They also have misconceptions, but they don't realize it. They thought students did not pay attention to them so they didn't understand the main ideas of the concepts. To watch these clips I know that I cannot assume that teachers know science content. I cannot ignore the details. I have to explain everything to them. (Somsri, Focus Group Interview)

During watching the video clips, Somsri also stated to the other professional developers that the clips told them that they could not assume that the private school teachers had good content knowledge. The excerpt above also implies that Somsri may design future PD that emphasizes developing content knowledge to teachers.

When the professional developers were asked about how the teachers' teaching met their goals or the PD goals, they indicated that in general the teachers had good teaching techniques. However, the ways that the teachers taught in classrooms did not align with the objective of the Standards. The professional developers also indicated that if teachers followed the IPST curriculum strictly, they would teach in the way required in the Standards. They indicated:

คือเทคนิคทั่วไปอะดี แต่ว่าแบบที่จะเอาไปใช้เพื่อให้ได้ตามจัดประสงค์ที่ต้องการมันไม่ตรง เพราะฉะนั้นจะต้องดู step ใดอะไร เราก็บอกแนะนำให้ใช้หนังสือ สสวท. เพราะเราวาง step ไว้ให้เพื่อจะให้ทำตามมาตรฐานที่กำหนดไว้

For the general teaching techniques, I think they are O.K. But, for the techniques in teaching science based on the Standards, I think they did not do it well. They did not follow the steps that we provided for them in the IPST curriculum. In the curriculum, we provided clear teaching steps that align with the Standards. (Piti, Focus Group Interview)

It is interesting that Piti, who held the pedagogy-driven orientation, was not disappointed with teachers' teaching strategies as much as Somsri. Piti did not closely look at the sequence and quality of teachers' use of the 5E model. He only indicated that if teachers used and followed the IPST curriculum, they would not have problems in teaching science. However, Somsri indicated that watching the video clips helped her to know that teachers did not teach science using the 5E model of instruction, which the professional developers tried to encourage them to do.

คนที่ 2 นี้ 2 ชั้นนี้พอใช้ได้นะ แต่ชั้นที่ 3 นี้ที่ว่าจะทดลองนี้ก็ไปได้ แต่ขาดขั้นที่ว่า อภิปรายและสรุปผลรวม พอนำไปขยายผลรู้สึกแกลสะเปะสะปะ ช่วงสุดท้าย ตอนขยายผลนะ คือมันจะดีกับ ช่วงสุดท้าย ตอนขยายผลนะ คือมันจะดีกับ คือเค้าไม่แมนในองค์ความรู้ แล้วก็เลยไปลงที่เด็ก ไม่ใช่ ถ้าเราดูแล้ว เพราะครู

For Chujai, her first two steps of the 5E are O.K. But, she did not do a good job on explanation and conclusion, which brought the confusion in the elaboration step. She did not have good content knowledge in helping students to understand about this concept [heat conduction]. But, she didn't know it. She taught, but students did not pay attention to her, which is not right. (Somsri, Focus Group Interview)

Somsri indicated that Chujai did not realize that her poor understanding of the concept she taught led to confusion among students. The video clips of teachers' teaching led Somsri to have the idea of providing a pre-lab before teaching science.

เห็นแล้วว่าครู misconception อย่างไร กระบวนการสอนอย่างไร คืออยากจะให้เค้าก่อนทำการทดลองให้เค้าชี้แจงกับเด็ก อย่างนี้เห็นได้เลยว่าควรมี pre-lab คือครูควรจะมี pre-lab ให้เรียบร้อยซะก่อนไม่ใช่มานอกทีละชิ้นๆ แล้วเด็กจะจับประเด็นอะไรไม่ได้เลย จะรวบยอดเลยไม่ได้

I can see how the teachers have misconceptions and how they teach in the classrooms. This clip brought me the idea about providing pre-lab to the students before the formal teaching. For example Manee, she should provide pre-labs to her students rather than telling students to follow her. So we can see that students did not learn any things. They didn't know what the main idea is. (Somsri, Focus Group Interview)

The excerpt above reveals that Somsri did not agree with Manee's teaching strategies that she directed students to follow her step-by-step during the activity.

However, Piti and Sommit indicated that they were satisfied with Manee's and Chujai's teaching. They indicated that at least the teachers allowed students to participate in hands-on activities.

คือจริงๆ สิ่งที่เราได้ไปก็อาจจะเป็นที่ว่าจะกล้าสอนโดยใช้การทดลองมากขึ้น ผิดถูกไม่ว่ากัน No matter it is right or wrong, I think at least teachers are brave to teach science and have students to do experiments. (Piti, Focus Group Interview)

กล้าให้เด็กได้ใช้อุปกรณ์มากขึ้นนะ ไข่ม้อย ธรรมดาจะไม่ค่อยกล้า Teachers also opened to students to use materials and equipments, which normally they were hesitant to do that. (Sommit, Focus Group Interview)

The excerpts above reveal that the professional developers believed that the PD was successful in that the teachers were not hesitant to teach science. In addition, there was a positive sign in that teachers allowed students to use scientific materials and equipment.

When asking Piti about how these clips helped him in terms of teachers' knowledge and future PD design, he indicated that:

เรารู้ว่าครูส่วนหนึ่งไม่รู้ แต่ไม่สามารถจะลงรายละเอียดได้ทั้งหมดทุกกิจกรรม โดยเห็นว่า
อย่างเช่นการสอนทุก step เราไม่สามารถจะบอกได้สอนอย่างนี้ไปอย่างนี้ๆ แล้วจะไปได้
ผลสรุปอะไร เพราะ concept มีมากมายที่เราจะต้องให้การอบรมในเวลาไม่มากนัก
เพราะฉะนั้นก็จะพูดกันเฉพาะ concept ที่พอจะพูดได้ไม่เสียเวลามาก กิจกรรมก็เป็น
กิจกรรมที่ค่อนข้างจะสำคัญ ครูควรจะทำอย่างนั้นเราถึงจะให้ ที่นี้ปรากฏว่าอย่างเร็วความถี่
ของเสียงเป็นอีกเรื่องที่เราไม่ได้ให้การทดลองเราไม่ได้ให้ทำ
I know that some teachers might not know the content and the pedagogy.
But, we cannot do every activity. We cannot tell every step and learning
outcome of each step because we have too many concepts to cover within
a limited timeframe. Thus, we have to select the activity that is not too
time-consuming. (Piti, Focus Group Interview)

When Piti was asked about future PD projects, he still mentioned that his PD design and implementation was limited by time restrictions.

ปัญหาก็คือขั้นตอนการสอนที่เราแสดงให้ดูไม่ได้เลย เนื่องจากเวลามัน.... คือเราอยาก
แสดงให้ดูเต็มๆ ทำไม่ได้ คำว่าเต็มๆ ก็คือ 1 ชั่วโมงเราไปไม่ได้ก็เรื่อง เราไปได้แทบจะ 1
สัระ อย่างที่ผ่านมาสอนเสียงกับไฟฟ้าคนละ 1 ชั่วโมง อย่างนี้ มันไม่รู้ก็กิจกรรม
เพราะฉะนั้นมันแสดงให้ดูไม่ได้จริงๆ มันควรจะมีการแสดงให้ดูสัก 1 ตอน
I wish I could model the steps of 5E clearer than I did. But, it is not
possible because I only have about one hour for teaching sound concepts
and another professional developer will have about an hour to teach
electricity and magnetism. Thus, we cannot model teaching of every
activity. (Piti, Focus Group Interview)

The professional developers learned from watching the video clips of teachers' teaching that teachers from the private schools also had limited content knowledge in science. They also learned that the teachers did not implement the 5E model of instruction in their classrooms. However, they still believed that the absence of all 5 steps of the 5E in the classroom was because these teachers did not follow the IPST curriculum seriously. In addition, the professional developers still believed that they could not

provide a full version of the 5E implementation during the PD because of the time restriction. The focus interview with the professional developers showed that although the video clips of teachers' teaching helped them realize about teachers' learning and teaching science, this information seemed to have little impact on their PCK for PD. Somsri was the only professional developer who mentioned that she would redesign the future PD by emphasizing more content knowledge to teachers. Other professional developers still believed that their PD design and implementation were limited by time restrictions. In addition, Piti and Sommit were happy that, although teachers did not have strong content knowledge, they did not hesitate to implement hands-on activities with their students. This could be explained by the orientations for PD that each individual professional developer displayed. For example, the video clips helped Somsri, who held didactic orientation and belief that teachers are knowledge tellers, to learn about teachers' knowledge of science. Watching the video clips influenced her belief about PD design in that she realized should not leave out the simple concepts, assuming that teachers might know them already. According to Sommit, the activity-driven orientation led him to be satisfied when teachers used hands-on only in the science classrooms without helping students connect the activities to conceptual understanding. Although Piti also held an activity-driven orientation, the orientation that served as a dominant role in this PD was pedagogy-driven orientation. Thus, I was surprised with his reflection on teachers' teaching when he agreed with Sommit that at least teachers allowed students to do science activities in the classrooms. He did not reflect on the teachers' use of 5E teaching approach in the classrooms. In addition, it seemed that the video clips of teachers' teaching would not influence his future PD design, although that remains to be seen. In

regards to Vimon, she watched the video clips quietly and did not mention anything during the focus group interview. Thus, it was difficult to claim how these clips influenced her PCK for PD.

In summary, the focus group interview with the professional developers helped me to understand that the orientations for PD influenced the ways that professional developers viewed the success of the PD. In addition, professional developers' learning about PD and their own teaching practice were also blocked by their orientations.

CHAPTER SIX: CONCLUSIONS AND IMPLICATIONS

The purpose for examining this entire PD project as a case was to understand the dynamic nature of science PD in a holistic manner. Research questions that guided analysis and writing up included: (a) What happens during the professional development workshop? (b) What are professional developers' orientations to professional development? (c) What do professional developers know about teachers, curriculum, instructional strategies, and assessment for professional development? (d) What knowledge do professional developers take into account during the professional development design process? (e) What happens during classroom teaching that takes place after professional development? (f) What are professional development participants' orientations to science teaching? (g) What do professional development participants know about students, curriculum, instructional strategies, and assessment for science teaching?

This chapter includes a synopsis of the findings, discussion of the findings in relation to the research literature discussed in Chapter Two, and implications for professional developers, science educators and researchers. I end this chapter with the recommendations for future research.

Synopsis of Findings

The first research question is to understand nature of the PD workshop. Based on my observations with the professional developers, I assert that the professional developers displayed a role as a knowledge provider while the professional developer participants were mostly passive recipients, who had less opportunity to communicate ideas, experience, and knowledge. The professional developers exhibited beliefs that

knowledge of science could be simply discovered through hands-on activities. In addition, all professional developers believed that they already provided necessary information, such as content knowledge, hands-on activities, lists of materials, and answers to each question in the activity worksheets and PD handbook. Thus, teachers must review that information on their own after they left the PD. Some professional developers, such as Piti and Somsri tried to model the 5E instructional approach to teachers during the PD workshop in order to encourage them to teach science using this teaching strategy. However, Piti and Somsri only emphasized the first three steps, but ignored the remaining two steps of the 5E model. Vimom and Sommit, on the other hand, focused on providing hands-on activities to teachers in order to help teachers have choices of activities to use with their students. The professional developers displayed their confusion about the explanation and elaboration steps in the 5E model.

According to second question of this study, the professional developers displayed multiple orientations, including activity-driven, discovery, didactic, and pedagogy-driven orientations. The majority of professional developers held activity-driven, discovery, and didactic orientations. The professional developers tried to cover the PD activities that they planned for the PD while providing correct information and knowledge to teachers. With regards to this study, I found a new orientation called pedagogy-driven orientation. I defined this orientation as the orientation in which the professional developer introduces pedagogy knowledge that necessary in science teaching. The professional developer presents information through lecture, activity, discussion and questions in order to develop an awareness of science teaching among teachers. In this orientation, the professional developer does not necessarily select PD activities to enhance content

knowledge of teachers. For example, the two professional developers who strongly exhibited the pedagogy-driven orientation emphasized content development less. Piti's belief about poor pedagogical knowledge of the elementary teachers about teaching science through inquiry led Piti to plan the PD to help the teachers address their needs. Rather than focusing on developing content knowledge about the concept of sound to teachers, Piti emphasized selecting and modeling the activities that would represent the 5E model of instruction. In addition, Piti kept reminding teachers about the teaching techniques that they should use in their classrooms.

Also, my analysis revealed that the four orientations displayed by the professional developers deviated from the Science Education Standards in Thailand. I found evidence that all professional developers displayed didactic, activity-driven, and pedagogy-driven orientations instead of inquiry, guided-inquiry, or other orientations that could serve the request of the Standards.

Science concerns learning about nature by man, who uses observation, investigation and experimentation of the natural phenomena and takes the results to formulate systems, principles, concepts and theories. Therefore the teaching/learning of science emphasizes the learner as the person doing the learning and discovering by him/herself so that process and knowledge are acquired from the pre-school years through education at tertiary level and post graduate level and even at the work place.
(Standards, p. 4)

The analysis revealed that the professional developers believed that knowledge is facts which can be learned by reading or telling from experts. In addition, the activity-driven, didactic, and pedagogy-driven orientations led to the results that the PD implementation of professional developers could not meet the aims of science teaching/learning as requested in the standards.

Furthermore, the professional developers exhibited inadequate PCK for PD, including knowledge of teachers' understanding of science, knowledge of PD strategies, knowledge of PD curriculum, and knowledge of assessment of teachers' scientific literacy. It is evident that the limitation of one type of knowledge resulted in limiting other types of PCK. The professional developers' knowledge and orientations influenced their selection of PD activities and teaching approaches. There was a relationship between the orientation of professional developers and their decisions in selecting the PD activities. I found that the professional developers selected the activities using 4 criteria, including: (a) introducing the science content and science teaching strategies that were required by the Science Education Standards, (b) hands-on and fun to do, (c) manageable in the classrooms, and (d) manageable in the PD.

According to teachers' knowledge, orientations, and practices, the majority of teachers displayed a didactic orientation to the science topics they taught. They also exhibited other orientations, including activity-driven, discovery, and academic rigor orientations. The orientations of these teachers were aligned with the professional developers in that they believed that knowledge was facts that could be transferred from teachers to students. The teachers provided hands-on activities to students without enough knowledge about the content that could be developed from doing those activities. To compare the teachers' orientations with the standards, their orientations were critical factors that influenced the absence of science teaching/learning strategies that aligned with the Standards.

The teacher participants demonstrated limited PCK. Their knowledge of students' learning of science, science teaching strategies, science curriculum, and assessment were

not adequate to teach science effectively. None of the teachers displayed an awareness of students' prior knowledge and difficulties to learn the concepts that were taught. They also did not demonstrate the specialized knowledge (Hill, Rowan, & Ball, 2005) in terms of knowing strategies or models to represent knowledge, understanding how these strategies work, knowing why the model, activity, and teaching strategy are useful in developing student understanding, and understanding the meaning of strategies, models, and procedure in teaching. The limited PCK led to the lack of an appreciation of science reasoning, understanding the meaning of scientific ideas and procedures, and knowing how ideas and procedures connect.

After watching the video clips of teachers' teaching, the professional developers acknowledged that teachers did not have adequate content knowledge of the topics they taught. However, the professional developers did not worry about the teachers' content knowledge or knowledge and ability in teaching science through the 5E approach. Rather, they were happy with the teachers' use of hands-on activities with their students. At the end of the focus interview, Piti and Sommit confirmed that what they did in the PD was the best they could do under the time restrictions.

Discussion and Conclusion

What Can Be Learned From This Study?

The overarching research question of this study was: What knowledge, orientations, and practices do science professional developers and professional development participants have and what are the consequences of these understandings? In response to the questions on knowledge, orientation, and practice of professional developers, I learned that the professional developers displayed orientations that

obstructed inquiry-based instruction as required by the Thai Standards. In addition to their orientations, limited PCK influenced the PD implementation and outcomes. Although I did not assess content knowledge of PD participants before and at the end of PD, the observation and discussion with teachers helped me to learn that teachers did not have sufficient content knowledge to teach science. In addition, the PD did not benefit teachers in developing in-depth structured content knowledge, or PCK of students, instructional strategies, curriculum, or assessment. Although the professional developers introduced the 5E model of instruction through modeling or instruction, they did not develop the teachers' ability to use this teaching model. Consequently, the professional developers did not meet their goal in terms of the PD participants' use of PD activities in their classroom through inquiry-based teaching approaches.

This study allowed me to learn that in order to develop teachers' knowledge, orientations, PCK and teaching practices we need to alter the professional developers' orientations and PCK for PD by recognizing the Dynamic of PD (as shown in Figure 20). However, where in this PD cycle that we should start? My four years of learning experiences in the Ph.D. program might help to answer this question.

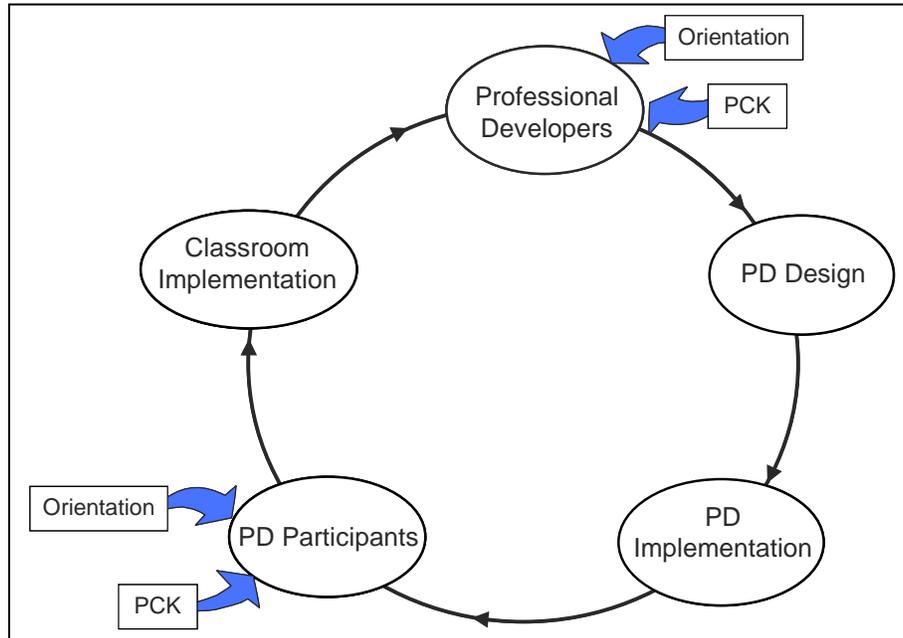


Figure 20. The Dynamic of Professional Development

My orientations and PCK for PD at the start of my doctoral program were similar to those of Vimon, one of the professional developers in this study. Before I started the Ph.D. program, I was trained to be a professional developer by the staff in the Department of Primary Science, IPST. I did not have classroom teaching experiences. The ways I learned about designing and implementing PD were from observation of my colleagues' teaching. Thus, I believed that, at that time, I held the activity-driven and didactic orientations. However, during the Ph.D. program, I continually developed knowledge and awareness about elementary science teaching and professional development through coursework, talking with experts, observing PD, and working on several PD research project . At the end of the Ph.D. program, I strongly believe that my orientation and PCK for PD are toward inquiry, although I still have not had formal classroom teaching experience. To relate my development of knowledge, orientation and PCK to the Dynamic PD cycle, I believe that we need to create cognitive dissonance in

the professional developers. In other words, we need to intervene in the PD Cycle at the phase that the professional developers observe and reflect on teachers' teaching. This dissonance experience will help the professional developers realize and develop awareness about teachers' teaching in their classrooms. It is important that the PD should include follow up opportunities for the professional developers to visit teachers' classrooms to observe their teaching, and chances to reflect with other professional developers what they can learn from these observations. These opportunities would help the professional developers to develop reflective thinking about the relations of teachers' practices and PD, which may lead them to think about their own teaching during the PD implementation. However, my experiences in the Ph.D. program indicated that this process of changing take time.

With regards to the teachers' knowledge, orientations, and practices, I learned that these teachers did not have adequate content knowledge or PCK in the topics that they taught. In addition, the teachers' orientations shaped their science teaching. Throughout the observations, teachers taught science from a didactic perspective and emphasized the development of students' factual knowledge rather than inquiry skills or conceptual understanding.

Extending the Magnusson et al. model of PCK, I noticed that the relations among knowledge components of PCK might be more complicated. The study showed that the lack of one type of knowledge influenced the use of other types of knowledge. For example, the teachers who displayed a didactic orientation believed that knowledge is transferable from one person to other persons. Thus, this orientation influenced decisions in assessment strategies and teaching methods. In addition, the limitation of knowledge of

students' learning difficulties and misconceptions led to the misuse of teaching strategies, curriculum, and assessment methods.

What Is The Significance Of This Study In Relation To The Research?

In Chapter Two, I discussed three gaps in the research literature that this study addresses. These gaps were (a) research on the professional developers' PCK, (b) research on PD in a holistic view, and (c) research about the PD context in Thailand. The findings of this study can address these three gaps in the literature as follows.

PD orientations and PCK. The first gap was research on professional developers' PCK for PD. I found no studies in the science education literature that focused on PCK of professional developers. This study contributes to the research literature in that I conducted a study with professional developers to investigate their PCK for PD. With this aspect, I designed a tool to explore professional developers' orientations for PD. I developed a set of scenarios for a card sort activity. I encouraged professional developers to reflect on each scenario and then sorted the scenarios that represented their own teaching from most to least.

At the beginning of the design of this study, I hypothesized that the PCK for science teaching (Magnusson et al., 1999) framework could be adapted to the study of professional developers' PCK for PD. The findings of this study show that the Magnusson et al. model can serve as a conceptual framework for understanding the professional developers' PCK for PD. I found that the professional developers in this study held didactic, activity-driven, and discovery orientations, which are similar to the orientations for teaching science. I also found that the orientations were held simultaneously and consistently. The professional developers' orientations for PD,

knowledge of teachers' learning, of PD curriculum, of PD strategies, and of assessment influenced their design and implementation of the PD.

Furthermore, this study allowed me to find a new orientation that could be added into a model of PCK for PD. This orientation is a pedagogy-driven orientation.

Professional developers who held this orientation will focus on introducing teachers to particular teaching strategies through either lecture, modeling, or doing hands-on activities. The professional developers who have the pedagogy-driven orientation pay less attention to developing content knowledge in teachers.

Holistic view of PD. The second gap in the research literature that I found was that, although many researchers conducted studies on design, implementation, and outcomes of PD, these typically were done in separate pieces. According to these research pieces, researchers found that PD experiences are intellectually superficial, disconnected from deep issues of curriculum and learning, fragmented, and non-cumulative (Ball & Cohen, 1999). In addition, teachers adopted a reform-based curriculum superficially, then continued to teach in traditional ways (Horizon Research, 2002; Keys & Kennedy, 1999; Olson, 1981; Welch, Klopfer, Aikenhead, & Robinson, 1981). With this gap in the literature, I hypothesized that investigating the nature of PD in a holistic view might help us to develop understanding of the dynamic of PD design, delivery, and outcomes. In addition, the holistic study would help us to understand other factors in the PD process that influence the design, implementation, and teachers' learning. In this study, I found that these factors include professional developers' orientations, PCK for PD, and knowledge about context (Guskey, 2000; Magnusson, Krajcik, & Borko, 1999)--teachers and schools.

Although Lee, Wang, Musikul, and Abell (2006, March) conducted a study with one PD project to understand the PD process in holistic manner, they did not observe the PD design, classroom teaching, or professional developers' reflection on teachers' teaching. Thus, the study could not deeply explain how the PD influenced teachers' learning and teaching, or how the outcomes of PD influence professional developers' learning about PD and about their own practice. The findings of the present study allowed me to learn that the professional developers' orientations for PD deviated from the Standards. Their orientations did not support teachers' learning and beliefs about science teaching. Thus, it was not surprising that teachers only adopted the PD activities and curriculum superficially and continued to teach in traditional ways.

The professional developers showed several conflicts between their knowledge and implementation. First of all, they believed that teachers had adequate knowledge for teaching science at primary grades. In addition, they believed that teachers could learn science content from doing activities during the PD. However, these professional developers also held another belief that teachers could not learn difficult contents from doing the activities. To teach difficult content, professional developers needed more time for telling. Thus, the professional developers did not spend adequate time to develop teachers' learning of the difficult science concepts. Instead, they selected activities that they believed that teachers could learn the science from by doing the activities. However, although the professional developers believed that teachers already understood the easy concepts and they could also learn from doing activities, three of four professional developers still provided content knowledge to teachers through lecture.

The second conflict was the role of activities in PD implementation. At the beginning, the professional developers discussed that doing activities could help teachers learn science content. However, probing their beliefs and their reflections on the video clips of teachers' teaching show that the professional developers held other beliefs about the role of PD activities. They believed that having teachers do the activities in the PD as they would teach in their classrooms would increase their confidence in teaching science. The second role of PD activities was to develop teachers' laboratory abilities. Taking into account both the first and second conflicts, there is no surprise that the professional developers did not see learning science content and doing activities as fitting together at some points. This also explained that why didactic and activity-driven orientations were integrated within the individual professional developers' beliefs.

The third conflict that I found within the professional developers was their belief about inquiry. Although the professional developers wanted teachers to implement inquiry-based approaches in their classrooms, they did not use the inquiry approach in the PD. The professional developers believed that teaching science through inquiry was time-consuming, while their time for PD was limited. Thus, the professional developers did not fully implement the 5E inquiry approach during the PD. They also did not make the strategies nor the benefits of inquiry in teaching and learning explicit to teachers. They anticipated that teachers would see the importance of inquiry and use it with their students. However, the third conflict of professional developers could be understood when they reflected on the video clips of teachers' teaching. These professional developers did not hold inquiry orientations for PD. Thus, they were not disappointed when they found that teachers did not implement inquiry in the classrooms. In addition,

the activity-driven orientation of professional developers led them to be satisfied when they knew that teachers adopted the PD activities, but still taught it in their own way without understanding the concepts.

Loucks-Horsley et al (2003) suggested in their model that the evaluation of PD outcomes would return back to and influence the professional developers' knowledge and beliefs. However, I found that the professional developers' learning about PD and about their own practice was blocked by their orientations. Instead of seeing the strength and weakness of PD and their own teaching, the evaluation of teachers' learning and teaching did not show any effects on the professional developers' knowledge and beliefs when the results matched with their orientations.

PD context. The third gap in the research literature was the research about the PD context in Thailand. Guskey (2000) indicated that a quality of PD is influenced by three factors, including content, process, and context. With regards to context, Guskey suggested that PD should be designed in ways that best suit organizational and individual contexts. In terms of PCK, knowledge of context is one of three factors that influences PCK (Magnusson et al., 1999; Grossman, 1990). Within this study, I found evidence that lacking knowledge about context influenced PD design and also impacted teachers' learning. According to this study, the professional developers did not acknowledge well enough about their participants and their schools. They made assumptions that the private school teachers had more content knowledge in science than the public school teachers. In addition, some professional developers made assumptions that teachers did not have enough materials and equipment in doing science activities. These assumptions affected their PD design.

In conclusion, to develop deep understanding about PD and teachers' learning, we as science educators and researchers needed to study PD in a holistic manner in order to understand how professional developers' orientation, PCK, and other knowledge influence the design and implementation of PD. Similar to classroom teaching, professional developers need to have a specialized form of knowledge that transforms subject matter knowledge, pedagogical knowledge, and context knowledge for PD and for elementary science teaching into an understandable form for teachers. In addition, this study found that professional developers' orientations and PCK are important to their PD design and implementation. Thus, I would suggest that in order to design and implement a quality PD, we need to realize how orientations and PCK for PD are important to develop a quality PD that helps teachers' learning and teaching.

Implications

Implications for Professional Development in Thailand

The need for developing PD that is coherent to teachers, especially in the Thailand context, is crucial to science educators and professional developers. Loucks-Horsley, Love, Stiles, Mundry, and Hewson (2003) explained that an effective professional development design takes into account the need for sustainability. Understanding the dynamic of PD design, delivery, and outcomes by examining PD in a holistic manner can help Thai professional developers to reflect about their orientations, practices, and PD outcomes, which will benefit their future PD design helping them support teachers and ultimately their students in the teaching and learning of science. Thus, this study provides implications for future PD in Thailand in that the PD needs to:

- Provide a supportive but challenging learning environment. PD should develop in-depth structured content and pedagogical knowledge, which establish connections to teachers' science classroom.
- Be designed as a long-term project that promotes development and changes in teachers' content knowledge, orientation, and practice. The PD must challenge teachers to change the didactic and activity-driven orientations toward an inquiry orientation.
- The PD should include assessment and follow-up opportunities in order to give feedback to teachers about their learning and teaching in order to help teachers improve their skills. In addition, the assessment and follow-up supports provide empirical evidence for the professional developers to enhance their PCK.
- The professional developers should help teachers, and also themselves, to realize that the isolation of content knowledge, pedagogy knowledge, knowledge of students, activities and assessment do not constitute effective science teaching.

Implications for Professional Developers in Thailand

Loucks-Horsley et al. (2003) explained that professional developers need a broad range of knowledge and skills in developing expertise in the content and pedagogical content of science education, organizational change, adult learning and development, coaching, evaluation, and professional development strategies. With regards to this study, I found that professional developers must develop expertise in PCK for PD including knowledge of teachers' learning, of PD strategies, of curriculum, and of assessment. This

study provides implications in that we might need to consider professional development for professional developers in order to increase adequate orientation and PCK for PD.

The professional developers might need to:

- Continually be aware and develop content knowledge, pedagogical knowledge, and PCK in order to effectively transform knowledge to teachers.
- Enhance understanding about PD strategies and assessment methods in order to help teachers understand how their existing beliefs and habits of practice influence to their interpretation of new ideas and practices.
- Develop understanding of the specifications of the 5E model that aims for teachers change their ways of teaching to a more effective way.

In order to meet the needs stated above, professional developers need to participate in PD that helps them to develop orientations for science teaching and for PD toward an inquiry orientation and also to develop PCK for PD. In this case, it is important for IPST to provide supports for professional developers' learning. First of all, according to the Dynamic of PD cycle (as shown in Figure 20), we learn that orientation and PCK for PD are critical for PD design and implementation, which eventually influence teachers' learning. It is important that IPST to be aware that the orientation and PCK of the professional developers deviated from the Science Education Standards. IPST should pay attention on providing learning opportunities for the professional developers to help them alter their PCK toward the reform minded ways. To meet this goal, IPST must ask professional developers to include follow-up opportunities for teachers in their PD plan. With the follow-up opportunity, professional developers can observe teachers' teaching in the classrooms, interact with teachers, and provide feedback to them. This will allow

the professional developers to develop reflective thinking about their knowledge, orientation, and PCK for PD and their relationships to PD and classroom implementation. IPST also should provide other learning opportunities for the professional developers, such as organizing seminars or colloquium sessions among the professional developers and also experts in science education. Based on my epistemological assumption that learning occurs through negotiation among persons, I believe that talking among experts and other professional developers will help the individual professional developer develop their knowledge and PCK for PD.

Second, IPST should encourage the professional developers to get involved in research experiences, including reading research articles, participating in research conference, or conducting research. These research experiences will provide opportunities for the professional developers to gradually develop worldwide knowledge about PD and teachers' learning.

Third, although knowledge and awareness of primary science teaching can be developed through the negotiation with experts, I believe that having real experience of teaching at primary levels is one of many ways that help the professional developers develop awareness about science teaching. Thus, IPST should provide opportunities for professional developers who do not have classroom teaching experience to teach in the classrooms. In addition to developing teachers' content knowledge, the Taxonomy of Teaching and Learning Model by Loucks-Horsley et al (2000) shows that professional developers need to help teachers to understand the teaching of science and its complexity. This goal for PD is difficult to be met if the professional developers do not have experiences in and understanding or awareness about classroom teaching.

Fourth, IPST should ask experienced professional developers who have strong knowledge and PCK to train beginning professional developers. Because each of them has different levels of experience and background in teaching, the experienced professional developers should serve a role as supervisors for these novices. For example, rather than letting the beginning professional developers design and implement PD on their own, the experienced professional developers should work closely with the novices in order to provide suggestions and challenge them in depth thinking about their plans and implementations. The experienced professional developers should observe the novices' teaching and provide ongoing feedbacks to them.

Finally, in order to promote and sustain intensive PD for novice and experienced professional developers, the professional developers, as a team, should set individualized goals for their teaching in the PD. During the PD implementation, professional developers should be video taped in their teaching, so that specific feedback could be provided in relation to these goals. In addition, the video clips of their PD teaching can provide windows for models of instruction, elicit problems of practice, and raise awareness of teachers' thinking and learning in science.

We might need multiple years for the changes of professional developers' orientations and PCK for PD to occur. Thus, IPST needs to understand the nature of this process and continually support and help its colleagues throughout this long-term process.

Limitations

The holistic view of PD allows me to learn that orientations and PCK of professional developers are critical to PD. However, this research has several limitations.

First, the study could not provide deep information about how much knowledge and PCK the teachers learned from the PD. If I had more times in doing this research, I would spend more time on looking at teacher participants' knowledge and teaching practice before they came to the PD and following up after the PD.

I learned about the card sort strategy and my specific process from doing this study. Based upon my experiences, the card sort activity would be richer if I would revise the card sort scenarios and also add more scenarios for the professional developers and teachers to reflect upon. I believe that having participants read and reflect on the scenarios as much as possible will allow me to have more evidence in developing understanding about their orientations, PCK, and the connections among the PCK components.

Recommendations for Future Research

The goals of this study were to understand the knowledge, orientations, and practices of professional developers and professional development teachers. However, this study was conducted in the context of Thailand where the research on PD and professional developers is remarkably limited. I believe that we need more research, in Thailand and other countries, on these areas in order to have ways to improve the quality of PD that could meet the teachers' needs. According to this study, I believe that there are several questions that needed to be answered. These questions include: What do professional developers learn from the teachers' teaching and how PD outcomes impact to their orientations and PCK for PD? What happens in future PD design and implementation? Do the orientation maps of individual professional developers change? How and to what degree do professional developers know about PD strategies, activities,

and representation in order to facilitate teachers' learning? Is there a root orientation for each individual participant, which orientation is stronger than others, and how does the root orientation influence the other orientations? How and in what ways do the PCK components connect to each other? Or what knowledge of curricula do the participants have?

Many researchers have studied teachers' subject matter knowledge and PCK for teaching science (Grossman, Wilson, & Shulman, 1989; Shulman, 1986; Zeidler, 2002). Many researchers also studied PD and characteristics of effective PD for decades. However, we do not see significant changes in teachers' learning, practice, or students' learning achievement. These days effective PD seems to be an idealistic vision rather than a realistic achievement. I think now it is time for researchers to step back to think about what PCK for PD professional developers should have in order to facilitate teachers' learning and teaching. What other orientations for PD do the professional developers display in common? In addition, I recommend researchers to develop more research using a holistic methodology in other contexts, such as in different countries, teachers, and PD structures.

Teaching and learning are a dynamic process. Thus, long-term PD, rather than short snap-shorts are needed in order to develop teachers' PCK and support them throughout the change process. Yet, what and how the PD should look must be grounded in the research literature as well as the needs and context of the particular PD. Thus, researchers must continue studying in this area that creates a holistic understanding about PD, professional developers' PCK, and teachers' learning. When these questions are able

to be solved, we may see the changes in science education in Thailand and around the world.

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Appendix A

Permission Letter for School Principals

July ..., 2006

Dear Principal of,

I am doing non-funded dissertation research. The purpose of this research is to develop understanding of the nature of Thai professional development.

The expected teacher participants in this study will be the staff members in your school. Thus, I would like to ask for your permission in allowing your staff member to participate in this study. The benefit from participation in this study is I will share the findings of my research with the teacher, which will help him or her to reflect about orientations, practices, and outcomes relate to professional development. This will benefit his or her science teaching.

The participating teacher will be asked to participate in several research activities: (a) three individual interviews– the first interview will be held during the PD design process, the second interview will take place at the end of PD project, and the third interview in October; (b) direct observation – this will take place during the PD delivery and in your classroom; and (c) unobtrusive data such as copies of PD lesson plan, curriculum, or handouts.

All of responses will be kept strictly confidential. Only my advisor, my committee members, and I will see completed interview transcripts and only I will know participants' name. If the participants agree to let me tape the interview and video tape their teaching, the audio and video tapes will be kept on file for three years. No results will be reported in a manner that would allow a reader to associate any responses to individual respondents. Participating in this study will not subject participants to risks greater than those normally encountered in everyday life.

Please understand that the participation is voluntary, the participants' refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled, and they may discontinue your participation at any time without penalty or loss of benefits. Also, they do not have to answer any questions that may be asked. If you should have any questions or concerns about this research project, please feel free to contact investigator.

Kusalin Musikul
301O Townsend Hall
University of Missouri – Columbia
Columbia, MO 65211

or

237/1 Ramindha 61
Tha Rang, Bangkok
Bangkok 10230
Phone (06) 617-1969

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For additional information regarding human participation in research, please feel free to contact the UMC Campus Institutional Review Board.

Campus IRB Compliance Office
483 McReynolds Hall
Columbia, MO 65211
(573) 882-9585.

You also may email the Campus IRB Compliance Office at umcresearchcirb@missouri.edu.

Regards,

Kusalin Musikul

Doctoral Candidate - Curriculum & Instruction
303 Townsend Hall
University of Missouri
Columbia, MO 65203
Email: km497@mizzou.edu

Sandra Abell, PhD
Professor

303 Townsend Hall
University of Missouri
Columbia, MO 65203
Email: AbellS@missouri.edu

If you are willing to allow your staff to participate in this project, please sign, date, and return this permission letter to the investigator.

I, _____, agree to participate in this research study.
(Print your name here)

(Sign your name here)

(Date)

(Investigator's signature)

(Date)

Appendix B

Written Consent Form for Teachers

July..., 2006

Dear Participating Teacher,

I am doing non-funded dissertation research. The purpose of this research is to develop understanding of the nature of Thai professional development.

If you decide that you want to be part of this research, you will be asked to participate in several research activities: (a) three individual interviews– the first interview will be held during the PD design process, the second interview will take place at the end of PD project , and the third interview in October; (b) direct observation – this will take place during the PD delivery and in your classroom; and (c) unobtrusive data such as copies of PD lesson plan, curriculum, or handouts.

All of your responses will be kept strictly confidential. Only my advisor, my committee members, and I will see completed interview transcripts and only I will know your name. If you agree to let the investigator tape the interview and video tape your teaching, the audio and video tapes will be kept on file for three years. No results will be reported in a manner that would allow a reader to associate any responses to individual respondents. Participating in this study will not subject you to risks greater than those normally encountered in everyday life.

Please understand that your participation is voluntary, your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled, and you may discontinue your participation at any time without penalty or loss of benefits. Also, you do not have to answer any questions that may be asked.

If you should have any questions or concerns about this research project, please feel free to contact investigator

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Campus IRB Compliance Office

483 McReynolds Hall

Columbia, MO 65211

(573) 882-9585.

You also may email the Campus IRB Compliance Office at umcresearchcirb@missouri.edu.

If you are willing to participate in this project, please complete the consent form below.

Regards,

Kusalin Musikul

Doctoral Candidate - Curriculum & Instruction
303 Townsend Hall
University of Missouri
Columbia, MO 65211
Email: km497@mizzou.edu

Sandra Abell, PhD
Professor

303 Townsend Hall
University of Missouri
Columbia, MO 65211
Email: Abells@missouri.edu

Consent Form

I, _____ agree to participate in the research project conducted by Kusalin Musikul, a doctoral candidate in the College of Education, Department of Learning, Teaching, & Curriculum at the University of Missouri – Columbia.

I understand that:

- My participation is voluntary and that I must be 18 years of age to participate.
- My identity will be kept confidential.
- I will not need to provide personal background information other than past teaching experiences.
- I understand that all interviews will be audio and video-taped.

I have read the letter above and am aware that I may contact Kusalin Musikul with any questions or concerns.

I consent to the use of research data as described above and understand that I am free to withdraw consent and to discontinue participation in the study at any time.

Participant's Signature

Date

Participant's Name

Appendix C

Permission Letter for IPST

July ..., 2006

Dear President of the Institute for the Promotion of Teaching Science and Technology,

I am doing non-funded dissertation research. The purpose of this research is to develop understanding of the nature of Thai professional development.

The expected professional developer participants in this study will be the staff members in the Primary Science Department, IPST. Thus, I would like to ask for your permission in allowing your staff members to participate in this study. The benefit from participation in this study is I will share the findings of my research with IPST and staff members at Department of Primary Science, which will help them to reflect about their orientations, practices, and outcomes related to professional development. This will benefit them and IPST as a whole for future professional development.

The professional developer participants will be asked to participate in several research activities: (a) two individual interviews– the first interview will be held during the PD design process and the second interview will take place at the end of PD project; (b) direct observation – this will take place during the PD delivery; (c) card-sorting task – this will take place at the same time with the first interview; and (d) unobtrusive data such as copies of PD lesson plan, documents, or descriptions of PD tools.

All of responses will be kept strictly confidential. Only my advisor, my committee members, and I will see completed interview transcripts and only I will know participants' name. If the participants agree to let me tape the interview and video tape their teaching, the audio and video tapes will be kept on file for three years. No results will be reported in a manner that would allow a reader to associate any responses to individual respondents. Participating in this study will not subject participants to risks greater than those normally encountered in everyday life.

Please understand that the participation is voluntary, the participants' refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled, and they may discontinue your participation at any time without penalty or loss of benefits. Also, they do not have to answer any questions that may be asked.

If you should have any questions or concerns about this research project, please feel free to contact investigator.

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Regards,

Kusalin Musikul

Doctoral Candidate - Curriculum & Instruction
303 Townsend Hall
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Email: km497@mizzou.edu

Sandra Abell, PhD
Professor

303 Townsend Hall
University of Missouri
Columbia, MO 65203
Email: AbellS@missouri.edu

If you are willing to allow your staff to participate in this project, please sign, date, and return this permission letter to the investigator.

I, _____, agree to participate in this research study.
(Print your name here)

(Sign your name here)

(Date)

(Investigator's signature)

(Date)

Appendix D

Written Consent Form for Professional Developers

July ..., 2006

Dear Professional Developer,

I am doing non-funded dissertation research. The purpose of this research is to develop understanding of the nature of Thai professional development.

If you decide that you want to be part of this research, you will be asked to participate in several research activities: (a) three individual interviews– the first interview will be held during the PD design process, the second interview will take place at the end of PD project , and the third interview in October; (b) direct observation – this will take place during the PD delivery and in your classroom; and (c) unobtrusive data such as copies of PD lesson plan, curriculum, or handouts. I will also ask for your permission for audio taping your interview and video taping your implementation.

All of your responses will be kept strictly confidential. Only my advisor, my committee members, and I will see completed interview transcripts and only I will know your name. If you agree to let the investigator tape the interview and video tape your teaching, the audio and video tapes will be kept on file for three years. No results will be reported in a manner that would allow a reader to associate any responses to individual respondents. Participating in this study will not subject you to risks greater than those normally encountered in everyday life.

Please understand that your participation is voluntary, your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled, and you may discontinue your participation at any time without penalty or loss of benefits. Also, you do not have to answer any questions that may be asked.

If you should have any questions or concerns about this research project, please feel free to contact investigator

Kusalin Musikul		237/1 Ramindha 61
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For additional information regarding human participation in research, please feel free to contact the UMC Campus Institutional Review Board.

Campus IRB Compliance Office
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(573) 882-9585.

You also may email the Campus IRB Compliance Office at umcresearchcirb@missouri.edu.

If you are willing to participate in this project, please complete the consent form below.

Regards,

Kusalin Musikul

Doctoral Candidate - Curriculum & Instruction
303 Townsend Hall
University of Missouri
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Email: km497@mizzou.edu

Sandra Abell, PhD
Professor

303 Townsend Hall
University of Missouri
Columbia, MO 65211
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Consent Form

I, _____ agree to participate in the research project conducted by Kusalin Musikul, a doctoral candidate in the College of Education, Department of Learning, Teaching, & Curriculum at the University of Missouri – Columbia.

I understand that:

- My participation is voluntary and that I must be 18 years of age to participate.
- My identity will be kept confidential.
- I will not need to provide personal background information other than past teaching experiences.
- I understand that all interviews will be audio and all observations will be video-taped.

I have read the letter above and am aware that I may contact Kusalin Musikul with any questions or concerns.

I consent to the use of research data as described above and understand that I am free to withdraw consent and to discontinue participation in the study at any time.

Participant's Signature

Date

Participant's Name

Appendix E

Professional Developers' Interview Protocols

Representative Sample of Individual Professional Developer Interview Protocols

First Semi-Structured Interview Protocol: During the PD design process

1. What are your goals of PD for teachers and for their students?
2. What benefits the teachers will have from participation in PD?
3. Why teachers need to have PD? What is essential of PD?
4. What difficulties do you think teachers have in learning heat conduction?
5. How do you help teachers to overcome those difficulties?
6. What difficulties do you think teachers have in teaching this topic?
7. What prerequisite knowledge do teachers need to know in order to teach this topic?
8. How do you plan to help teachers develop that knowledge?
9. What PD strategies do you plan to use to teach this topic?
10. Why do you think these strategies can help teachers learn?
11. How is this curriculum different to the others?
12. Have you taught this topic before?
13. What are the goals of this curriculum for teachers? And for students?
14. Why do you settle on the target number of 200 participants?
15. Why a 3-day workshop with 8 sessions? What was the rationale for the format of the workshop?
16. What do you think teacher's need to be able to teach the new curriculum?
17. To what degree your prior knowledge about teaching and learning impact the PD design process?
18. What PD strategies have you tried in the past and how successful were they?
19. How do you know when the teachers learn?
20. What PD strategies do you plan to use in this PD project? Why?
21. What do you do in terms of assessing teachers' learning? Why do you decide to use this strategy? or why do you not plan for assessment?

Second Semi-Structured Interview Protocol: After PD project

1. What difficulties do you have when you teach this unit?
2. How do you know teachers learn this unit?
3. What parts of this unit are difficult for teachers to learn?
4. What do you think you learn from teaching this unit in terms of teacher learning difficulties?
5. If you have to teach this unit again, how do you plan to solve this problem?
6. What do you think you learn from teaching this unit in terms of PD curriculum?
7. If you have to teach this unit again, will you redesign the curriculum? Why or why not?
8. What do you think you learn from teaching this unit in terms of the strategies you used in the project?
9. If you have to teach this unit again, will you use the alternative PD strategies? Why or why not?

10. In terms of PD activities, how do think these activities helps teachers learn?
11. If you have to teach this unit again, are you going to use the same PD activities? Why?
12. What do you think you learn from teaching this unit in terms of teacher learning assessment?
13. If you have to run this PD project again, what else do you plan to change? Why?
14. How do you conceptualize this PD project? How is it similar or different than the previous projects?
15. How do you plan to support teachers in a long run?
16. How do you satisfy with this PD project?

Focus Group Interview Protocol

1. What do you expect to see in these clips?
2. What did you see that you think shows fidelity to your PD instruction?
3. What expected teaching practices did you not see from the clips?
4. How do you feel about their implementations?
5. Having seen these teachers' classroom, what do you think about the PD you offered? Do you plan to make any changes in the future? Why or why not?

Appendix F

Teachers' Interview Protocols

Representative Sample of Individual Teacher Interview Protocols

First Semi-Structured Interview Protocol: Used to explore teachers' knowledge of science curricula, of students, of assessment of science literacy, and of instructional strategies

1. What are your experiences with learning science both in and out of school?
2. Describe the most positive experiences that you had with learning science. What makes them the most positive ones?
3. What is your favorite science topic to teach? Why?
4. What do you think are the reasons for studying science at the elementary school?
5. What are the goals for your students to learn about heat conduction? Why is it important for students to know?
6. What are the goals for your students to learn about dissolution? Why is it important for students to know?
7. What are the goals for your students to learn about sound? Why is it important for students to know?
8. What are the goals for your students to learn about electricity? Why is it important for students to know?
9. What learning difficulties do you think students have in heat conduction?
10. How will you help students to learn about this topic?
11. What activities that you think will help students understand about heat conduction? Why do you decide to use those activities?
12. What learning difficulties do you think students have in dissolution?
13. How will you help students to learn about this topic?
14. What activities that you think will help students understand about dissolution? Why do you decide to use those activities?
15. What learning difficulties do you think students have in sound?
16. How will you help students to learn about this topic?
17. What activities that you think will help students understand about sound? Why do you decide to use those activities?
18. What learning difficulties do you think students have in electricity?
19. How will you help students to learn about this topic?
20. What activities that you think will help students understand about electricity? Why do you decide to use those activities?
21. How this reformed-curriculum different to the previous one? What are the goals of this curriculum?
22. What parts of curriculum do you teach? Not teach? Why?

Second Semi-Structured Interview Protocol: Will use when teacher plan to teach a unit (before teaching)

1. Why do you think it is important for students to learn heat conduction?
2. What goals do you have for your students in this unit?
3. What do you intend the students to learn about heat conduction? What else in this topic that you think your students should not learn yet? Why?

4. What difficulties are you expecting connected with teaching heat conduction?
5. What learning difficulties do you think students have in heat conduction?
6. What misconceptions do you expect your students to have?
7. How many days do you plan to teach this unit? Why x-day class?
8. How will you organize the instruction (teaching procedures)? What teaching strategies you are going to use?
9. Why do you think these strategies can help students learn?
10. What activities do you plan to use with your students?
11. Why do you think these activities will help students learn this topic?
12. How will you assess your students' understandings?
13. Why do you decide to use these assessment strategies?
14. Are there other ways that you might use to assess your students?
15. How you know your students learn this topic?
16. In what ways the experiences you have gain from this PD will influence your current teaching science?

Semi-structured interview protocol: After teaching

1. Do you think the unit is successful? Why?
2. What are the strengths of your teaching this unit?
3. What parts of this unit are difficult for students to learn?
4. If you have to teach this unit again, are you going to use the same instructional strategies? Why?
5. If you have to teach this unit again, are you going to use the same activities? Why?
6. What do you think that students learn from this unit? How do you know that?
7. What difficulties do you have when you teach this unit?
8. What do you think you learn from teaching this unit?
9. What can you tell me about the changes to your teaching compared to your teaching before participated PD? In what degrees your teaching has change?

Appendix G

Sample of Activity Manual in the PD Handbook

Activity 20: How does pitch occur?

กิจกรรม 20 เสียงสูงเสียงต่ำขึ้นกับอะไร

แนวคิดหลัก — เสียงที่มีความถี่สูงจะให้เสียงสูง หรือเสียงแหลม และเสียงที่มีความถี่ต่ำจะให้เสียงต่ำหรือเสียงทุ้ม

ผลการเรียนรู้ที่คาดหวัง — ทดลองและสรุปผลได้ว่าวัตถุที่สั่นด้วยความถี่สูงจะให้เสียงสูง และวัตถุที่สั่นด้วยความถี่ต่ำจะให้เสียงต่ำ

เวลาประมาณ — 2 ชั่วโมง

แนวการจัดกิจกรรม —

1. ใช้การเปิดเทปที่บันทึกเสียงความถี่เดียวไว้ (อาจเป็นเสียงต่ำต่อเนื่องเพียงเสียงเดียวจากการสั่นของมอเตออร์หรือเสียงสูงเพียงอย่างเดียวจากการใช้เลื่อยตัดโลหะ) ให้นักเรียนฟังแล้วสังเกตผลเปรียบเทียบกับเทปบันทึกเสียงคนตรี หรืออาจให้นักเรียนลองออกเสียงความถี่เดียว จากนั้นให้ตัวแทนนักเรียนร้องเพลงให้คนอื่น ๆ ฟังเปรียบเทียบกับการออกเสียงความถี่เดียว โดยครูตั้งคำถามให้นักเรียนคิดดังตัวอย่าง
 - เสียงความถี่เดียวกับเสียงคนตรีอย่างไรน่าจะฟังมากกว่ากัน เพราะเหตุใด
 - เสียงสูง - ต่ำของเสียงคนตรีขึ้นกับสิ่งใด
2. ให้นักเรียนช่วยกันอภิปรายจนสรุปได้ว่า เสียงความถี่เดียวเป็นเสียงน่าราคาญ เสียงคนตรีหรือเสียงเพลง เป็นเสียงที่น่าฟัง เพราะมีเสียงสูง เสียงต่ำเป็นจังหวะ จากนั้นจึงตั้งประเด็นปัญหาว่า เสียงสูงและเสียงต่ำขึ้นกับสิ่งใดบ้าง เพื่อนำไปสู่การสำรวจและค้นหาต่อไป

Key Concept

Learners' Expected Outcomes

Activity Time Duration

Materials

1. แก้วน้ำชนิดมีก้น
2. น้ำ
3. ยางรัด
4. กล้องไม้
5. ดินสอ
6. ไม้บรรทัด
7. ขวดแก้วชนิดเดียวกัน
8. เครื่องดนตรี เช่น กีตาร์ ระนาด ฆ้องวง อังกะลุง เป็นต้น

การเตรียมล่วงหน้า — นอกเหนือจากวัสดุอุปกรณ์ทั่วไปที่ต้องติดต่อขอยืมเครื่องดนตรีบางชนิดไว้ล่วงหน้า เช่น กีตาร์ ระนาด อังกะลุง เป็นต้น

Preparation Prior Teaching

3. นักเรียนทำการทดลองสังเกตการสั่น และเสียงที่เกิดขึ้นจากสิ่งต่อไปนี้

3.1 ใช้นิ้วถูวนรอบปากแก้วที่ใส่น้ำไว้ไม่เท่ากัน

3.2 ใช้นิ้วเคาะขวดที่บรรจุน้ำไม่เท่ากัน

3.3 ตีคymbal ที่ซึงตั้งบนกล่อง เลื่อนดินสอให้บางส่วนที่ถูกตียาวไม่เท่ากัน 2 ค่า

3.4 ตีคymbal ที่ซึงเส้นใหญ่สุด และเล็กสุด เปรียบเทียบกัน (อาจให้เขย่าอังกะลุง อันใหญ่สุดและเล็กสุดหรือตีระนาดที่ถูกระนาดยาวสุดและสั้นสุด เปรียบเทียบกัน)



1. ใช้นิ้วถูวนรอบปากแก้วที่ใส่น้ำไว้ไม่เท่ากัน 2. ใช้นิ้วเคาะขวดที่บรรจุน้ำไม่เท่ากัน



3. ตีคymbal ของที่ซึงตั้งบนกล่อง 4. ตีคymbal ที่ซึงเส้นใหญ่สุด

? คำถาม - คำตอบ

วัตถุที่ให้เสียงสูง จะสั่นเร็วหรือช้ากว่าวัตถุ ที่ให้เสียงต่ำ

ตอบ วัตถุที่ให้เสียงสูงสั่นเร็ว หรือมีความถี่สูงกว่าวัตถุที่ให้เสียงต่ำ

4. ให้นักเรียนเสนอผลการทดลอง และร่วมกันอภิปราย ซึ่งควรได้ข้อสรุป ดังตัวอย่างต่อไปนี้

4.1. แก้วน้ำที่บรรจุน้ำไว้น้อยจะมีมวลน้อยและสั่นด้วยความถี่สูงกว่าแก้วที่บรรจุน้ำมากหรือมีมวลมาก แก้วที่บรรจุน้ำน้อยให้เสียงสูง ส่วนแก้วที่บรรจุน้ำมากให้เสียงต่ำ

4.2 เมื่อเคาะขวดที่ใส่น้ำปริมาณต่างกัน ขวดที่ใส่น้ำไว้น้อยจะมีมวลน้อยกว่าและเมื่อเคาะจะสั่นด้วยความถี่สูงให้เสียงสูง ส่วนขวดที่ใส่น้ำไว้มากจะมีมวลมาก เมื่อเคาะจะสั่นด้วยความถี่ต่ำและให้เสียงต่ำ

4.3 ในการใช้ขางรัดซึงตั้งบนปากกล่องแล้วตีคymbal ให้สั่นพบว่า ถ้าเลื่อนดินสอจนทางด้านที่สั้นมีมวลน้อย เมื่อตีแล้วจะสั่นด้วยความถี่สูงและให้เสียงสูง แต่เมื่อตีคymbal ด้านที่ยาวกว่าซึ่งมีมวลมากกว่าจะสั่นด้วยความถี่ต่ำ และให้เสียงต่ำ

4.4 เครื่องดนตรีอื่นๆ เช่น กีตาร์ ระนาด ฆ้องวง อังกะลุง เมื่อตีหรือเคาะชิ้นส่วนของเครื่องดนตรีที่มีมวลน้อย ชิ้นส่วนนั้นจะสั่นด้วยความถี่สูง และให้เสียงสูง ส่วนชิ้นส่วนของเครื่องดนตรี ที่มีมวลมากจะสั่นด้วยความถี่ต่ำ และให้เสียงต่ำ

5. จากผลการทดลอง นำมาอภิปรายร่วมกันจนได้ข้อสรุปว่า เสียงสูงและเสียงต่ำขึ้นกับความถี่เสียง ซึ่งตรงกับความถี่ในการสั่นของแหล่งกำเนิดเสียง

Activity Directions

ใบบันทึกกิจกรรม 20

ชื่อ..... ชั้น..... เลขที่.....

วันที่..... เดือน..... พ.ศ.



เสียงที่สังเกตจากการทำกิจกรรม

ผลที่สังเกตได้จากการทำกิจกรรมเป็นดังนี้

Table shows Observation Results

วัตถุ	ลักษณะ	การสั่น (เร็ว, ช้า)	เสียง (สูง, ต่ำ)
แก้วน้ำ	น้ำเต็มแก้ว น้ำ 1/4 แก้ว ช้า เร็ว ต่ำ สูง
ขวดน้ำ	น้ำเต็มขวด น้ำ 1/4 ขวด ช้า เร็ว ต่ำ สูง
ยางรัดของ	ยาว สั้น ช้า เร็ว ต่ำ สูง
สายกีตาร์	เส้นใหญ่ เส้นเล็ก ช้า เร็ว ต่ำ สูง

- การสั่นของแหล่งกำเนิดเสียงสัมพันธ์กับเสียงสูง และเสียงต่ำหรือไม่ อย่างไร
(การสั่นของแหล่งกำเนิดเสียงสัมพันธ์กับเสียงสูง และเสียงต่ำ โดยแหล่งกำเนิดเสียงที่สั่นด้วยความถี่สูงจะให้เสียงสูง และแหล่งกำเนิดที่สั่นด้วยความถี่ต่ำจะให้เสียงต่ำ)
- สรุปผลการทดลองนี้ได้ว่าอย่างไร
(เสียงสูงและเสียงต่ำขึ้นกับความถี่เสียง โดยเสียงความถี่สูงจะให้เสียงสูง และเสียงความถี่ต่ำ จะให้เสียงต่ำ)

Answers of Activity Questions

Content Knowledge for Students



เนื้อหาสาระ

ความถี่ในการสั่นของวัตถุเกี่ยวข้องกับมวลของวัตถุด้วย วัตถุที่มีมวลน้อยจะสั่นด้วยความถี่สูงกว่าวัตถุที่มีมวลมาก ความถี่เสียงที่เกิดจากการสั่นของวัตถุที่มีมวลน้อยจึงสูงกว่าความถี่เสียงของวัตถุที่มีมวลมาก

เมื่อเสียงมีความถี่สูง เราจะได้ยินเสียงสูงหรือเสียงแหลม และเสียงที่มีความถี่ต่ำ เราจะได้ยินเสียงต่ำ หรือเสียงทุ้ม



ความรู้สำหรับครู

การที่วัตถุมวลน้อยสั่นด้วยความถี่สูงกว่าวัตถุมวลมากนั้น เป็นจริงเฉพาะกรณีที่เป็นวัตถุชนิดและรูปร่างเดียวกัน เช่น ขวดน้ำที่มีมวลของขวดและน้ำน้อยกว่าเมื่อเคาะ จะมีความถี่ในการสั่นสูงกว่าขวดที่มีมวลของขวดและน้ำมากกว่า หรือสายกีตาร์เส้นใหญ่มีมวลมาก เมื่อดีดจะสั่นด้วยความถี่ต่ำสายกีตาร์เส้นเล็กที่มีมวลน้อย (เมื่อทั้งสองสายมีความตึงและความยาวเท่ากัน) แต่ถ้าเรานำมวลของวัตถุ 2 ชนิดมาเปรียบเทียบกัน เช่น นำมวลสายกีตาร์และมวลขวดน้ำมาสรุปว่า ความถี่จากการเคาะขวดน้ำ (มวลมาก) ต่ำกว่าการดีดสายกีตาร์ (มวลน้อย) ไม่ได้ เพราะความถี่ในการสั่นขึ้นกับความหนาแน่นและรูปร่างของวัตถุด้วย และยังมีปัจจัยอื่นที่เกี่ยวข้อง อีกมาก



ข้อเสนอแนะ

1. ครูอาจให้นักเรียนทำกิจกรรมได้หลายวิธี ดังนี้
 - 1.1 ให้ทุกกลุ่มทำการทดลองในกิจกรรมนี้ ซึ่งควรสังเกตการดีดยางรัด และสายกีตาร์ก่อน หรือ
 - 1.2 เลือกทำการทดลองบางกิจกรรม หรือ
 - 1.3 ให้ตัวแทนแต่ละกลุ่มไปร่วมกันทำการทดลองแต่ละอย่าง แล้วกลับมาอธิบายให้คนอื่น ๆ ในกลุ่มฟัง แล้วช่วยกันสรุปผลเพื่อนำเสนอต่อชั้นเรียน
2. ในการทดลองควรย้ำให้นักเรียนสังเกตว่า
 - 2.1 ในการทดลองแต่ละตอนเกิดเสียงหรือไม่ อย่างไร มีสิ่งใดเป็นแหล่งกำเนิดเสียง
 - 2.2 เสียงสูงและเสียงต่ำที่เกิดขึ้นสัมพันธ์กับการสั่นของแหล่งกำเนิดเสียงหรือไม่ อย่างไร

Content Knowledge for Teachers

ประเมินผล

Evaluation

- ประเมินทักษะในการทำกิจกรรม และทักษะการสังเกตจากสภาพจริงในการทำกิจกรรม
- ประเมินทักษะในการสรุปและอภิปรายผลจากการอภิปรายและการรายงาน ผลการทดลอง
- ประเมินผลการนำความรู้ไปใช้อธิบายปรากฏการณ์ต่างๆ จากการตอบคำถามของนักเรียน

การบูรณาการ

บูรณาการเข้ากับเรื่องสมบัติของสารเกี่ยวกับมวลและความถี่ของวัตถุ

Integration with other Science Areas

Suggestions for Teachers

Appendix H

Sample of Content in Misconception Book

What are differences between suspended, solution, and colloid substances

สารละลาย คอลลอยด์ สารแขวนลอย แตกต่างกันอย่างไรร

ในหนังสือเรียนวิทยาศาสตร์ระดับชั้น ป. 6 ได้กล่าวถึงลักษณะ สมบัติ และตัวอย่างของสารละลาย และสารแขวนลอย ซึ่งเป็นสารผสมไปแล้ว คอลลอยด์ก็เป็นสารผสมอีกประเภทหนึ่งที่มีสมบัติที่คล้าย และสมบัติเฉพาะตัวที่แตกต่างกับ สารละลายและสารแขวนลอย ดังนี้

Explanation of suspended substance

สารแขวนลอย เป็นสารเนื้อผสมที่ประกอบด้วยอนุภาคที่มีขนาดเส้นผ่านศูนย์กลางมากกว่า 10^{-4} (0.0001) เซนติเมตร กระจายอยู่ในของเหลวหรือแก๊ส ถ้าอนุภาคที่อยู่ในสารแขวนลอยมีขนาดใหญ่มาก จะมองเห็นส่วนผสมได้ชัดเจน เมื่อตั้งไว้จะตกตะกอน แต่ถ้าเป็นอนุภาคขนาดเล็กจะกระจายผสมกลมกลืนจนมองเห็นเสมือนเป็นเนื้อเดียวกัน เราสามารถแยกออกจากกันได้ด้วยการกรองด้วยกระดาษกรอง หรือทำให้ตกตะกอน ตัวอย่างเช่น น้ำโคลน น้ำแป้ง

Explanation of solution substance

สารละลาย เป็นสารเนื้อเดียวที่ประกอบด้วยองค์ประกอบสำคัญ 2 ส่วน คือ ส่วนที่มีปริมาณมากกว่า เรียกว่า ตัวทำละลายกับส่วนที่มีปริมาณน้อยกว่า เรียกว่า ตัวละลาย อนุภาคของตัวละลายจะมีขนาดเส้นผ่านศูนย์กลางน้อยกว่า 10^{-7} (0.0000001) เซนติเมตร จึงผ่านกระดาษกรองได้ และยังสามารถผ่านเซลล์โลเฟนได้อีกด้วย ตัวอย่างเช่น น้ำเกลือ น้ำเชื่อม สารละลายค่างทับทิม สารละลายจุนลี

คอลลอยด์ เป็นสารที่ประกอบด้วยอนุภาคของสารที่มีขนาดเส้นผ่านศูนย์กลางอยู่ระหว่าง 10^{-7} - 10^{-4} เซนติเมตร กระจายอยู่ในตัวกลางที่เป็นของเหลวหรือแก๊สอย่างถาวร และมองเห็นเป็นเนื้อเดียว อนุภาคของคอลลอยด์สามารถผ่านกระดาษกรองได้ แต่ไม่สามารถผ่านเซลล์โลเฟน⁽¹⁾ ตัวอย่างเช่น นํ้านมหมอก มัลค็อฟแมกนีเซีย น้ำกะทิ นํ้าสบู่

นอกจากนี้คอลลอยด์ยังมีสมบัติเฉพาะอย่างอื่นอีก คือ เกิดปรากฏการณ์ทินคอลลด์ และมีการเคลื่อนที่แบบบราวน์เนียน ซึ่งจะ ไม่กล่าวถึงรายละเอียดไว้ในที่นี้

Explanation of colloid substance

VITA

Kusalin Musikul grew up in rural Kamphaengphet Province, Thailand, where she completed her primary and secondary education. She had been to Perth, Western Australia for 1 year as a Rotary Youth Exchange student when she was at grade 11. She received a Bachelor of Science, majoring in Chemistry, from Chulalongkorn University in Bangkok, Thailand. Kusalin continued her study in Chemistry and received a Master of Science from Chulalongkorn University. Shortly thereafter, Kusalin accepted a fulltime academician position with the Institute for the Promotion of Teaching Science and Technology (IPST) in Bangkok, Thailand. She worked for two years in the Department of Primary Science to develop K-6 Chemistry textbooks and teacher guidebooks. She also had responsibility to provide professional development to primary teachers who teach science.

Kusalin completed her doctoral degree program from the University of Missouri – Columbia (MU). During her four years at MU she worked on several research grants in science and mathematics education. Dr. Sandra K. Abell was her program advisor and dissertation chair. They developed a strong collegial relationship over the years through various research projects.

In June of 2007 Kusalin will start working at the Department of Primary Science at IPST in an academician position. Her future career will continue her work on improving the quality of science teachers at primary levels and developing resources for teaching science in K-6 classrooms in Thailand.