

THESIS

**A DEVELOPMENT OF PROGRAM FOR PRIMARY SCHOOL
TEACHERS ON NATURE OF SCIENCE INSTRUCTION**

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THESIS

**A DEVELOPMENT OF PROGRAM FOR PRIMARY SCHOOL
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**A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
Doctor of Philosophy (Science Education)
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This two-year empirical research project explores four non-science lower primary school teachers' understanding of the Nature of Science (NOS) both in conceptions and instructional approaches and their teaching practices in Science. The NOS refers to the values and assumptions inherent in science, scientific knowledge, and the development of scientific knowledge. Teachers with appropriate understanding of the NOS and NOS instructional approaches teach Science more effectively and attend to developing students' scientific literacy. Based in the interpretist paradigm and using case study methods, the journeys of the participant teachers are described. The first exploratory year (2004) examines teachers' existing NOS understanding and teaching practices by employing semi-structured interviews, the NOSI Questionnaire, documentary and content analysis, and classroom observation. The second year (2005) traces the impact of an in-service primary school teacher professional development program on the teachers' instruction of NOS by employing the same sets of research instruments. The program was aimed at enhancing their understandings and teaching of the NOS. The impact of the training program, which was based on explicit approaches for the NOS instruction and social constructivist approaches for teacher development, is examined.

Findings from the first year reveal that teachers' views of the NOS ranged between traditional and contemporary. They did not recognize or appreciate the need to understand the NOS as a cognitive learning outcome that required explicit teaching and assessment. Rather, they used the implicit approach for teaching the NOS with an emphasis on studying scientific concepts and less emphasis on doing scientific activities. Findings from the second year following the professional development program revealed that the use of explicit approaches for the NOS instruction and employing a teacher development program based on social constructivist perspectives exerted considerable influence on teachers' understanding of the NOS instruction. The collaborative learning activities, opportunities for discussion, explicit reflection on their current understandings of the NOS concepts and instruction, and opportunities to undertake practical activities enhanced teachers' learning and understanding. Overall, teachers had more contemporary views of NOS. They appreciated the need to understand the NOS as an objective of Science teaching. They used more practical activities related to science processes in their Science teaching. Most of them appreciated the importance, and the use, of explicit instructional approaches relevant to the NOS. This study provides empirical evidence that when teachers are involved in a teacher development program based on social constructivist perspectives and focusing on explicit approaches for the NOS instruction, their understandings of NOS concepts are enhanced and they develop an appreciation of teaching the NOS in Science classes.

Student's signature

Thesis Advisor's signature

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CHAPTER I

INTRODUCTION

Background of Research Study

This research aims to study lower primary school teachers' understanding of the Nature of Science both in concepts and teaching of the Nature of Science as well as to develop their understanding of the Nature of Science instruction. In order to develop in-service teacher understanding and teaching of the Nature of Science, there are much more complicated issues to consider in both the international and the Thai contexts of science education.

The background that leads to the research questions of this study and the rationale for investigation will be further clarified in the following sections. Then, the scope of this research will be presented in the outline of the study. Finally, the significance and scope of this study will be summarized in the last section as well as the overview of the whole research.

1. Educational Reform in Thailand

Educational reform in Thailand began in 1997 and has been important for the whole country since the proclamation of the National Educational Act B.E. 2542 (1999). It is to supply the needs of individuals, as well as the social and economic development of the country (ONEC, 1998; 1999). Among the various key aspects of educational reform, a reform of teachers, faculty staff and educational personnel and a reform of science education are emphasized. Teachers, faculty staff and educational personnel were considered as important key factors for the reform. They would support the learning reform and the reform of teaching and learning process to emphasize a more student-centred approach (ONEC, 2002).

1.1 Reform of the training system for teachers and administrators of educational institutions

One of the key aspects of the reform of teachers, faculty staff and educational personnel is a reform of the training system for teachers and administrators of educational institutions. For in-service teacher development, the Office of the Education Council (OEC) has introduced the school-based training (SBT) as a new, effective and sustainable method of teacher training (OEC, 2004). This SBT method is a design based on a new paradigm to effectively develop teachers and the teaching profession which is related to critical theory for teacher development and a social constructivist paradigm. Teachers and schools have been empowered to develop their own teaching profession based on their own context. This method of training is also designed for promoting learner-centred pedagogies based on constructivist learning theory (Office of Commercial Services, 2002; Office of the Education Council, 2004).

However, there are some constraints to the design and delivery of the teacher development program based on a new idea of SBT to promote learner-centred learning. It is recognized that teachers and teacher educators in many teacher education institutes lack knowledge and skills related to this current innovation in training teachers and in new teaching approaches such as student-centred learning. Thus, it has been suggested that the “international best practices and the associated research and literature” should be introduced and balanced with local knowledge (Office of Commercial Services, 2002: 32). The in-service teacher-training curriculum should translate learning theories and abstract approaches into simple and practical language. This is so teachers can see the value in theoretical knowledge. It is recommended that an activity central to professional development should be to develop teachers’ understanding of teaching practices and underlying principles for new learning strategies, so teachers can change their beliefs about their practices, then adapt and innovate alternative effective learning activities. The in-service teacher-training program’s content, quality of design, and production of materials should also be revised. The program should have detailed classroom activities and templates of

lessons for modelling by teachers in the practicalities of using new teaching and learning strategies. It is also suggested that there should be alternative models of delivering training offered to teachers by relating to their context and teaching loads and providing long-term support to raise and expand their expertise (Office of Commercial Services, 2002).

1.2 Reform of science education

In the realm of educational reform, an ultimate goal for science education in Thailand is the development of a scientifically and technologically literate society. The scientific and technological literacy emphasizes understanding of scientific process as a process of knowledge construction; knowing scientific concepts; having process skills; having decision-making skills; and practicing scientific and rational thinking. The scientifically literate society emphasizes being a society with rational and systematic thoughts, learning by scientific process, and applying and using science in daily life (IPST, 2003; ONEC, 2001).

This ultimate goal has been emphasized in science education reform to solve the problem of a lack of interest in learning, using, and developing science and technology in Thai society. This is because generally most Thai people view science and technology as something which is complex and hard to understand. Governors and politicians view science and technology as only one of a variety of educational disciplines. Thus, there is a lack of funds for research and development in science and technology. The development of science and technology is also left for only one government organization to take the whole responsibility. It is not for everybody in society to take charge of science and technology development and application. Additionally and importantly, Thai people usually consume technology without critical thinking and scientific discretion. As a result of this background, Thai society is facing a lack of scientific infrastructure and competitive competency for international economic and industrial competition and a lack of ability to cope with rapid changes of culture and impacts of globalization, and to deal with the demand for sustainable environmental conservation (ONEC, 2001).

In order to reform science education, one key aspect is to develop the quality of teachers of Science. Teachers have important roles in developing and implementing a science school-based curriculum based on the new science standards documents for teaching and learning science established by IPST (2003). Teachers are also required to have understanding and knowledge in science; appropriate scientific attitudes and attitudes toward science; and understanding of pedagogy in science teaching including inquiry learning approach, ICT, and learning materials and resources development (ONEC, 2001).

To develop the quality of science teachers at a basic educational level, IPST and various teacher institutes under the Ministry of Education (MOE) have organized various training programs and workshops for science teachers (ONEC, 2001). One important project for training science teachers around the country is the training of master trainers (master teacher trainers). Master trainers are teachers from primary and secondary schools who directly participate in training programs organized by IPST and use what they have learned to train other in-service teachers in their schools or education regions (Soydhurum, 2001). Another attempt to improve the quality of science teachers is to train teachers via the Educational Television program (ETV). This distance training program has been developed because there is a high number of science teachers to be trained who are spread all over the country. This training program could help save time and budget in training as the teachers do not have to leave their schools to participate in the program. Additionally, by using this program, all teachers will be trained by the same qualified trainers at the same time which will ensure the quality of the training. Teachers can also download training manuals from IPST websites (Science-Mathematics-Technology Educational Cooperation Project, 2004).

However, some research indicated that both of these training programs organized by IPST still need to be improved in some aspects such as master teacher trainers face the problems of lacking facilities e.g. laboratory equipment, text books and documents, and learning resources and media to use in training other teachers; master teacher trainers lack time, funding, and support from school administrators;

trainee teachers need to know new teaching techniques; and some trainee teachers need to receive direct and face-to-face training rather than distance training (Petchuen, 2000; Research Department of IPST, 2003).

2. Situation of Science Education in Primary Schools in Thailand 1996-2004

Before the reform, Science at primary school level, Grades 1-6, had been taught as integrated within the group of subjects of Life Experiences. Teachers could not manage their teaching for achieving aims and objectives of science education. Students lacked opportunities to practice scientific process skills and thinking skills, and to develop scientific attitudes and appropriate attitudes toward science and learning science. Teachers usually taught Science by lecturing, reading, writing, and memorizing content (ONEC, 2001). The pilot study of this research also found similar results from classroom observation and informal interviews. Lower primary school teachers usually taught by lecturing and discussion with emphasis on scientific facts and concepts. They used some hands-on activities and exercises in student workbooks or work sheets purposely to develop students' understanding of those scientific facts and concepts. The science process skills, scientific attitudes, and concepts of the Nature of Science are rarely found as being explicitly taught or emphasized.

After the proclamation of new science standards documents, primary schools have to develop their own science curriculum. The structure of science teaching is becoming clearer at primary school level. Science can be taught as both individually specific subjects or integrated with other subjects. Primary school teachers are required to pay more attention to teaching Science by using an inquiry learning approach and other hands-on and minds-on learning activities in order to achieve the aims and objectives of science education (IPST, 2003).

However, in spite of the requirement of science education reform, most teachers in primary school who teach Science do not have a degree in teaching Science. Most teachers lack an understanding of scientific process skills. They also do not have enough time to develop their science teaching profession because of high

workloads in the schools. Additionally, most primary school teachers do not like to learn and teach Science. They have negative attitudes toward Science and teaching Science and a lack of confidence in teaching Science. Thus, these problems contribute to teachers' lack of ability in developing primary school students' appropriate attitudes and science process skills (ONEC, 2001; Soydhurum, 2001).

Rationale for Investigation

1. Importance of Understanding of the Nature of Science

Understanding of the Nature of Science is a prerequisite of science literacy. It is also one of the major goals of science instruction. Conceptions and instruction of the Nature of Science have been indicated explicitly in many reformed curriculum documents in many countries (Lederman, 1992; AAAS, 1994 Austin, 1997; McComas and Olson, 1998; NSTA, 1998; Haidar, 1999; Hand *et al.*, 1999; Akerson, Abd-El-Khalick, and Lederman, 2000; IPST, 2003).

Teaching and learning about the Nature of Science can encourage a person who is literate in contemporary science by helping them to understand the nature and relationship between science and technology, to know the history of science ideas and the role of science and technology in their personal life and society, to critique their everyday situations concerning scientific issues, and to make effective argumentation and apply basic scientific concepts to those situations (Hand *et al.*, 1999). Understanding of the Nature of Science also enhances students' learning of science content, awareness of moral and ethical values, and decision-making (Driver *et al.*, 1996; McComas *et al.*, 1998). It also enhances teachers' changing views of learning and teaching of Science. Teachers who have a contemporary view of the Nature of Science would be most likely to make more use of inquiry-based or constructivist teaching (Lederman, 1998; McComas *et al.*, 1998).

In primary school science education, there is an assumption that students should begin to learn about what science is and what scientists do and think at this

level, because young students already have potential to study these things (Etheredge and Rudnitsky, 2003; Harlen, 1996; Skamp, 2004). Many research studies have confirmed that students had already developed some firm ideas about what science is and scientists look like when they were about five years old (Hand *et al.*, 1999; Skamp, 2004). Thus, primary school teachers should not avoid conveying the appropriate concepts of the Nature of Science to their primary school students even at the lower primary school level.

In Thailand, the Institute for Promoting Science and Technology Teaching (IPST), which has responsibility for developing science standards documents and promoting teachers in teaching Science, has appreciated the importance of understanding the Nature of Science for a long time (ONEC, 2001). The understanding of the Nature of Science is recommended as an objective of learning Science for basic education. In the reformed national standards for teaching Science (2003), the content strand for the Nature of Science and Technology and its intended learning outcomes has been explicitly stated. IPST also has tried to promote teaching approaches which convey understanding of the Nature of Science such as the inquiry-oriented and problem-solving instructional approaches (IPST, 2003).

Soydhurum (2001), the president of IPST, reported that some schools, in order to convey an understanding of the Nature of Science, have adopted the inquiry-oriented instructional approach in their science instruction which was promoted by the institute. However, the implementation of this inquiry teaching approach has not commonly occurred in every school. He has also commented that the Ministry of Education and the Thailand Research Funds (TRF) suggested, based on the research findings, that “school science education in Thailand needed to be improved in both content and scientific process ... [because it has mostly emphasized] ... rote learning rather than individual thinking” (Soydhurum, 2001: 34). Thus, science education in Thailand still can not promote students’ appropriate understanding of the Nature of Science and appropriate attitudes toward science.

2. Teachers' Understanding and Teaching of the Nature of Science

It is commonly accepted that teachers are playing a vital role in developing students' understanding of the Nature of Science at school level. Teachers are required to have an adequate understanding of the Nature of Science and know how to help students construct their understanding of the Nature of Science (Lederman, 1992; AAAS, 1994; McComas *et al.*, 1998; NSTA, 1998; Hand *et al.*, 1999; Abd-El-Khalick and Lederman, 2000).

However, most research found that teacher understanding of the Nature of Science is generally limited, simplistic, unclear, and inadequate for teaching the Nature of Science according to the requirements of contemporary science curriculum (Rampal, 1992; Abell and Smith, 1994; Lakin and Wellington, 1994; Ogunniyi *et al.*, 1995; Lederman, Wade and Bell, 1998; Murcia and Schibeci, 1999; Akerson *et al.*, 2000; Eick, 2000; Gess-Newsome, 2002; Akerson and Abd-El-Khalick, 2003). Their teaching of Science usually misses opportunities to convey appropriate concepts of the Nature of Science by explicitly and implicitly addressing some aspects of the Nature of Science in their teaching. Some experienced teachers do teach Science as being consistent with their appropriate views of the Nature of Science by using many inquiry-oriented activities. However, these teachers do not purposely emphasize concepts of the Nature of Science as their goals of instruction and students' learning outcomes. Additionally, some teachers have an appropriate view of the Nature of Science but they do not teach it as being consistent with their views because they do not appreciate the importance of understanding of the Nature of Science as equal to understanding of scientific knowledge. Teachers also do not believe that their students can learn concepts of the Nature of Science (Tobin and McRobbie, 1997; Lederman, 1999; Akerson and Abd-El-Khalick, 2003).

In order to develop teachers' understanding and teaching of the Nature of Science, it is important to emphasize developing teachers' Nature of Science pedagogical content knowledge (NOS PCK). This means teachers should have adequate understandings or conceptions of various aspects of the Nature of Science,

as well as the knowledge of how to teach those aspects of the Nature of Science effectively (Abd-El-Khalick and Lederman, 2000; Akerson and Abd-El-Khalick, 2003; Hipkins, Barker and Bolstad, 2004). A program for in-service teacher professional development on the Nature of Science conceptions and instructions should be constructed based on the grounded perspective of social constructivism. A teacher development model and approaches to teacher development based on the social constructivist perspective should be applied. The program should also emphasize the explicit approaches for the Nature of Science instruction to serve as 'conceptual tools' for teachers to elicit and clarify their existing conceptions and construct or reconstruct their conceptions of the Nature of Science. The design of activities within the teacher professional development program should emphasize four specific aspects: developing teachers' understanding of the rationale behind the teaching of the Nature of Science; giving teachers' extensive experience in teaching and assessing the Nature of Science; giving teachers support in their field experiences; and developing teachers' intention to teach the Nature of Science explicitly (Abd-El-Khalick, Bell, and Lederman; 1998; Clough, 1998; Bell, Lederman and Abd-El-Khalick, 2000; Schwartz and Lederman, 2002).

Not many research studies have been found which investigate development of teachers' NOS PCK in Thailand. There was some survey research which studied Thai teachers' understanding of concepts of the Nature of Science in various aspects such as the nature of scientific knowledge; scientific method; and interrelation between science, technology, and society. In general, both primary and secondary school teachers across this research had an appropriate understanding of concepts of the Nature of Science. However, the findings of how teachers understand and the factors influencing their understanding are not consistent among the research studies (Bunmuangsan, 1997; Pholthum, 1997; Yotsapon, 1997; Khantha, 1998; Suksringarm and Suksringarm, 1998; Kingsoda, 1999; Phomburom, 1999; Taiyarat, 1999; Srivinate, 2000; Guanamol, 2000; Meesarphan, 2000).

Because of limitations of survey research, the real situation of the relationship between teachers' understanding of the Nature of Science and their classroom practice

has not been well studied. This relationship has only been inferred through quantitative analysis with statistical accounts. Although teachers generally seem to have adequate conceptions of the Nature of Science, the realistic picture of teachers' understanding and their teaching of the Nature of Science in Thai classroom context is still vague.

Additionally, there is a lack of the deep information needed to develop an in-service primary school teachers' teaching of science program in this area because research in science education rarely focuses on studying teachers' understanding and teaching of the Nature of Science in real classroom contexts. The development of Thai teachers' NOS PCK has not been explicitly studied in Thai science educational research.

From the pilot study using interviews and a questionnaire, this research has found that lower primary school teachers already have some conception of the Nature of Science. However, some conceptions may not be consistent with a contemporary view of science and teachers could not clearly explain these concepts verbally. Teachers seem to appreciate the objectives of teaching Science as developing student ability to think, work and solve problems scientifically and critically as well as to apply scientific knowledge in daily life. They also appreciate the teaching approaches of inquiry learning, research and self-study, and group work for students so they can construct knowledge by themselves. These findings seem to infer that lower primary school teachers seem to know how to teach Science to be consistent with the Nature of Science.

However, from observation it seems that their teaching is not consistent with their understanding and appreciation of science and teaching Science. Teachers seem to emphasize teaching scientific facts and concepts for memorizing rather than practicing students' science process skills, scientific thinking, and scientific attitudes. Thus, it is possible that teachers may not really understand how to teach Science by conveying appropriate concepts of the Nature of Science although they seem to appreciate teaching approaches related to what science and scientific inquiry is. This

may be the result of their unclear understanding of the Nature of Science and how it relates to the nature of teaching and learning Science, and their inability in designing science lessons and activities for conveying appropriate concepts of the Nature of Science.

These inferences still need further study. It is important to discover whether or not primary school teachers, especially general teachers who have to teach Science as one of many subjects, really recognize and appreciate the instruction of the Nature of Science. Additionally, although primary school teachers may have appreciation, it is unclear whether they recognize the influence of their understanding of the Nature of Science on their teaching practice, and whether they understand how to convey the appropriate concepts of the Nature of Science to their students.

Outline of the Study

This research studies lower primary school teachers of Science in order to support the attempt to reform science education at primary school level. Lower primary school teachers' understanding of concepts and instruction of the Nature of Science and their teaching practice are key variables in this study. This research also studies the impact of a research intervention on these key variables and its effectiveness. The intervention is an in-service primary school teacher professional development program on the instruction of the Nature of Science.

Because of the lack of deep information about lower primary school teachers' understanding of the Nature of Science and their teaching practice, this research design uses both qualitative and interpretive methodology in studying the current situation of participant teachers. This methodology is also used to study the impact and effectiveness of the intervention on participants' understanding and teaching of the Nature of Science.

The research is divided into three main phases. The first phase is to investigate lower primary school teachers' understanding of the Nature of Science both in

conceptions and instruction, their teaching practice of the Nature of Science, and factors which influence their instruction of the Nature of Science. The findings from this phase are used as the fundamental data for the development of an in-service professional development program and its training manual and materials in the second phase. The design is also based on the grounded perspective of social constructivism and the application of a teacher development model with emphasis on the explicit approaches for the instruction of the Nature of Science. In the last phase, the intervention was implemented and then checked for its effectiveness on developing lower primary school teachers' understandings of concepts and instruction of the Nature of Science and their teaching practice.

1. Research Aims and Research Questions

This research has two major aims. The first aim is to develop in-service primary school teachers' understanding of the Nature of Science in both conceptions and instruction. This is so they can organize learning processes and activities which can help students to achieve the intended learning outcomes of the Nature of Science and Technology content strand.

As the consequence of the first aim, the second aim is to propose and develop an effective program for in-service primary school teacher professional development on the instruction of the Nature of Science. This program is used as a tool for promoting teacher understanding and teaching of the Nature of Science.

This research has four major research questions.

1. Do primary school teachers have understandings of the instruction of the Nature of Science?

1.1 How do primary school teachers understand concepts of the Nature of Science?

1.2 How do primary school teachers understand the Nature of Science instructional approaches?

2. Do primary school teachers teach the Nature of Science? What are the factors affecting their instruction of the Nature of Science?

3. How does an in-service primary school teacher professional development program on instruction of the Nature of Science affect primary school teachers' understanding and teaching of the Nature of Science?

4. What do primary school teachers think about the advantages and disadvantages of an in-service primary school teacher professional development program on instruction of the Nature of Science?

2. Anticipated Outcomes

It was anticipated that this professional development program would effectively improve teachers' understanding and teaching of the Nature of Science in their real classroom practice. Additionally, other science educators and researchers would be able to apply the findings of this research and its intervention, including training manual and materials, in similar contexts of science teacher professional development in Thailand.

3. Delimitation of the Study

This research is a case study to develop lower primary school teachers' understanding and teaching of the Nature of Science through an in-service primary school teacher professional development program on instruction of the Nature of Science. The same four non-science specialist lower primary school teachers participated in all three phases of this research study. They are general classroom teachers from one typical middle-sized public primary school, under the Office of the Basic Commission, located in Nontaburi province in the central region of Thailand.

4. Definitions of Terms

Understanding of the instruction of the Nature of Science in this research refers to the understandings of concepts and instructional approaches of the Nature of

Science. There are five major groups of concepts of the Nature of Science which teachers should have understanding: definition of science; characteristics of scientific knowledge; development of scientific knowledge; characteristics of scientists; and interrelation between science, technology, and society. Teachers' understanding of the Nature of Science in each particular concept can be varied in the range of traditional view, mixed view, and contemporary view and in the range of misconception to correct conception. Teachers' understanding of the instructional approaches of the Nature of Science composes of; the appreciation of the importance of the Nature of Science as instructional cognitive learning outcomes, the intention to teach concepts of the Nature of Science in the context of science subject, and the understandings of characteristics of the explicit instructional approach for the Nature of Science.

Teaching of the Nature of Science in this research refers to the teaching and learning of Science by integrating the Nature of Science concepts and instructional approaches into science courses in order to develop learners' understanding of the Nature of Science as well as scientific concepts, science process skills, and scientific attitudes. Teachers' teaching of the Nature of Science can be varied in the range of using implicit approaches to explicit approaches. The implicit approaches for teaching the Nature of Science in this research refer to any instructional approaches for Science including learning by doing science and practical work which do not incorporate some activities or discussions to make a connection between science-subject content and concepts of the Nature of Science nor explicitly point out and reflect concepts of the Nature of Science that are conveyed during practical work. The explicit approaches for teaching the Nature of Science in this research refer to any instructional approaches for Science including learning by doing science and practical work which incorporate some activities or discussions to make a connection between science-subject content and concepts of the Nature of Science or explicitly point out and reflect concepts of the Nature of Science that are conveyed during practical work.

Overview of Thesis

The study and development of an in-service primary school teacher professional development program on instruction of the Nature of Science is expected to be able to enhance science education reform at primary school level. This is because it helps develop the quality of teachers who are a key to the reform and a key to developing student understanding of the Nature of Science. This study enhances the teaching of the Nature of Science which is important to the development of a scientifically literate society. This is the ultimate goal of science education reform in Thailand.

The professional development program developed in this research, based on the grounded perspective of social constructivism and application of a teacher development model, could be a practical model to release the constraints to the design and delivery of a teacher development program based on a new idea of school-based training. Its training manual and materials could be useful for master teacher trainers and science educators as training resources for multiplication of training programs to other science teachers at a local level.

There are seven chapters in this thesis. The next chapter will review all of the components related to the development of teachers' understanding of the Nature of Science: definition, elements, and values of the Nature of Science instruction; philosophical perspectives underpinning the understanding of the Nature of Science; teaching approaches for the Nature of Science; and attempts to improve teacher understanding and teaching of the Nature of Science.

The third chapter will present the research methodology, research paradigm and research design used in the dissertation. This will include details of data collection and analysis technique as well as the trustworthiness of data collection and analysis.

The fourth chapter will present findings from the first phase of the research. The findings of each participant teacher considered in each case study will be presented in detail. Then, the findings of teachers' understandings of concepts and instructional approaches for the Nature of Science, their teaching practices, and factors effecting their teaching across four cases will be presented and discussed.

The fifth chapter discusses the development and details of an in-service primary school teacher professional development program on instruction of the Nature of Science which is the intervention of the research. Guiding principles of the program construction, procedure of program development, and program content and activities will be presented.

In the sixth chapter, research findings of phase three, discussion, conclusions, and recommendations will be presented. The findings of participant teachers' understanding of concepts and instructional approaches for the Nature of Science during and after program implementation will be presented as well as their teaching practice after the program and their perceptions of the program. This chapter will also present processes, contexts, and factors affecting the program implementation.

In the last chapter, all the findings will be concluded and discussed in order to answer research questions. There will be suggestions and recommendations for program improvement and its application to other schools.

CHAPTER II

LITERATURE REVIEW

The review of literature in this chapter will identify the theoretical background and basic assumptions underpinning research on the Nature of Science as the framework for this research. The first section reviews the definition of the Nature of Science. Although there is no one absolute definition, for the purposes of the research, an appropriate operational definition should be made. The second section reviews the values of the Nature of Science in science education. This is to indicate the importance of the Nature of Science and confirm the importance of research in this area.

The philosophical perspectives of the Nature of Science are reviewed in the third section. The Nature of Science has tentative, changing characteristics which are based on the changes of individual and social views of science and scientific enterprise over a period of time. These perspectives lead to two main conceptions of the Nature of Science represented in the form of statements; the conception of the Nature of Science based on a *traditional* view of science, and the conception of the Nature of Science based on a *contemporary* view of science.

In the science education context, the conception based on the traditional view is usually justified as a misconception. This is because it does not suit the science educator and curriculum standards required of teachers and students in the twenty first century. Additionally, there is another kind of conception which does not understand what science really does. This kind of conception has no dealing with the philosophical perspective. However, this conception is also defined as a misconception of the Nature of Science.

This research uses these conceptions of the Nature of Science as the measuring standard for identifying teachers' understanding of the Nature of Science. Teachers

will be categorized into several groups based on their view of science; traditional view, contemporary view, and mixed view between traditional and contemporary. In some conceptions which have no dealing with philosophical perspectives, teacher can also be grouped into misconception, naïve or appropriate view of science.

In order to clarify what aspects of the Nature of Science the teacher should understand, the consensus aspects of the Nature of Science are gathered from various groups of information resources as reviewed in the fourth section, elements of the Nature of Science. According to this review, 'the Nature of Science conceptual scheme' is constructed to be the framework of this research. This scheme is presented in the fifth section. It is recommended that teachers should have understanding of the Nature of Science in five main aspects: definition of science; characteristics of scientific knowledge; development of scientific knowledge; characteristics of scientists; and interrelation between science, technology, and society.

Teaching approaches for the Nature of Science are reviewed in the sixth section. The generally agreed characteristics for the Nature of Science instruction and the suggestions for teaching the Nature of Science in lower primary school are reviewed and summarized. These generally agreed characteristics and suggestions are important for teachers to understand and implement in their classroom practice, in order to effectively develop their students' understanding of the Nature of Science.

The review and conclusion from those sections serve as the guideline for the research instruments, data gathering and analysis. This review gives the scope of conceptions and teaching practice of the Nature of Science which teachers should understand or should develop. This research uses the Nature of Science conceptual scheme and generally agreed characteristics of the Nature of Science instruction derived from this review to study and develop participant teachers' understanding and teaching of the Nature of Science. The conception of the Nature of Science and teaching approach according with this conceptual scheme and characteristics of the Nature of Science instruction are the messages conveyed explicitly in the professional development program of this research.

In order to develop an effective professional development program for improving teachers' understanding and teaching of the Nature of Science, the last section reviews important issues related to this development. Previous research findings of teachers' understanding and teaching of the Nature of Science, and the assumptions and guiding principles of teachers' knowledge and development are reviewed. Finally, the general characteristics of an effective program for developing teachers' understanding and teaching of the Nature of Science are reviewed and summarized.

Definition of the Nature of Science

When talking about the Nature of Science, it is common to come up against the fuzzy issue about its meaning, both in its definition and its role in science education. Primarily, it is felt that the understanding of the Nature of Science is important. There is no one absolute definition of this term. NSTA noted that philosophers, historians, scientists, and science educators have not yet agreed on a single definition (NSTA, 1998). The conceptions of the Nature of Science itself are also considered by science educators as tentative and dynamic as having "changed throughout the development of science and systematic thinking about its nature and workings" (Dawkins and Glatthorn, 1998; Lederman, 1998; Akerson *et al.*, 2000: 298). Additionally, there are various definitions of this term in the literature (AAAS, 1994; Hand *et al.*, 1999; McComas *et al.*, 1998).

Lederman (1992) and Lederman *et al.* (1998: 331) referred to the Nature of Science as "the values and assumptions inherent to science, scientific knowledge, and/or the development of scientific knowledge" which included independence of thought, creativity, tentativeness, an empirical base, subjectivity, testability, and cultural and social embeddedness. They concluded that the Nature of Science was directly related to the epistemology of science, "science as a way of knowing" (Akerson *et al.*, 2000: 298), as distinct from science process and content. The NSTA used this definition, noting that generally the educational literature referred to the

concept of the Nature of Science as “the values and assumptions inherent in the development and interpretation of scientific knowledge” (NSTA, 1998: 17).

According to NSTA standards for science teacher preparation, the Nature of Science refers to:

- 1) Characteristics distinguishing science from other ways of knowing;
- 2) Characteristics distinguishing basic science, applied science and technology;
- 3) Processes and conventions of science as a professional activity; and
- 4) Standards defining acceptable evidence and scientific explanation (NSTA, 1998).

McComas *et al.* (1998: 4) stated that the Nature of Science is:

... a fertile hybrid arena which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavours.

Based on Lederman’s definition, in this research the Nature of Science is defined as: the values and assumptions inherent in science, scientific knowledge, and the development of scientific knowledge which represent unique characteristics of science as describing and explaining what the science is, how it works and how it is different from other disciplines, what the scientist has done in the society throughout history, and how science and the scientist interact with the society.

Values of the Nature of Science in Science Education

1. The Nature of Science in International Science Education

For a long time, the Nature of Science has been one of major goals of science instruction and the prerequisite of science literacy of many countries, especially in Europe and America (Lederman, 1992; AAAS, 1994; McComas *et al.*, 1998; NSTA, 1998; Hand *et al.*, 1999).

Since the 1960s, the Nature of Science has been promoted by science educators as the structure of scientific discipline to be the framework for science curriculum development and to be part of science instruction. This is for coping with the problems related to rapid expansion of knowledge in science during that period of time and the rapid changes in society (Robinson, 1968), as well as coping with the changing paradigm in science (Kuhn, 1962). Science educators attempted to emphasise the process and products of science, and some elements of the nature or structure of science such as inquiry learning, the nature of explanation, and the character of observation in formal school science curricula (Robinson, 1968; McComas *et al.*, 1998).

From the 1990s, the role of the Nature of Science in school science has been increasingly considered and accepted by many science educators and organizations throughout the world. Its concepts and instruction have been indicated in many reformed curriculum documents in many countries (Lederman, 1992; AAAS, 1994; Austin, 1997; McComas and Olson, 1998; NSTA, 1998; Haidar, 1999; Akerson *et al.*, 2000; IPST, 2003).

Many science educators and researchers claimed the importance of teaching and learning about the Nature of Science as promoting a person who is literate in contemporary science (Hand *et al.*, 1999). By learning to understand the nature and relationship between science as inquiry and technology as design, by knowing the history of science ideas and the role of science and technology in their personal life

and society, students will be able to critique their everyday situations concerning scientific issues, make effective argumentation, and apply basic scientific concepts to those situations (Hand *et al.*, 1999). Understanding of the Nature of Science also enhances students' learning of science content, awareness of moral and ethic values, and decision-making (Driver *et al.*, 1996; McComas *et al.*, 1998). It also enhances teachers' changing views of learning and teaching of Science. Teachers who have a contemporary view of the Nature of Science would be most likely to make more use of inquiry-based or constructivist teaching (Lederman, 1998; McComas *et al.*, 1998).

2. The Nature of Science in Thai Science Education

The issue of teaching and learning the Nature of Science has been considered within Thai science education as well as in all other countries. As part of the Thai education reform, the Institute for Promoting of Teaching Science and Technology (IPST), under authority of Thai Ministry of Education, had established a new science curriculum framework and science teacher standards in alignment with the national education guidelines within Thai National Education Act B.E. 2542 (1999). These standards documents explicitly recommend the consideration of this issue in various aspects which are discussed below.

2.1 Definition and Elements of the Nature of Science

IPST has identified the Nature of Science by explaining its elements which can be categorized into three main aspects; the development of scientific knowledge, the nature of scientific knowledge, and interrelationship between science, technology and society (IPST, 2003). These elements are regarded as based on the contemporary view of the Nature of Science concepts. (For more detail, see section Elements of the Nature of Science page 35).

Additionally, IPST recommended the scientific attitudes which students should achieve from learning Science in the following aspects:

Scientific Mind/ Scientific Attitudes are the characteristics or habits of mind in each person which develop when learning by using the scientific process. These characteristics are curiosity, creativity, circumspection, collaboration, broad-mindedness, perseverance, reasoning, responsibility, and trustworthiness (IPST, 2003: 73).

2.2 Visions, Aims, Objectives, and Outcomes for Learning of the Nature of Science

The vision of learning Science in the Manual of Content of Science Learning (IPST, 2003: 2-3), is that every learner should be encouraged to be interested and enthusiastic in learning Science, having curiosity and questioning the natural world, attempting and enjoying research, inquiry for knowledge, correcting data and analyzing data for answering questions, having the ability to make reasonable decisions by using data, and having the ability to communicate questions, answers, data, and findings from the study to other people.

From the same manual, this new science curriculum also aims at developing students to be science literate and has at least four objectives of science education regarding the Nature of Science.

Nature of Science is:

1. For understanding boundaries, nature, and limitations of science;
2. For developing thinking processes and imagination, ability in solving problems and management, communication skills, and ability in making decisions;
3. For recognizing the relationship between science, technology, people, and the environment and their effects and impact on each other;
4. For being individuals who have scientific attitudes, morals, ethics, and values in using science and technology creatively (IPST, 2003: 4).

In attempting to achieve these aims and objectives, one new science content strand called “The Nature of Science and Technology” has been created. Its learning outcomes have been explicitly set as:

Students should:

1. Understand the relationship between science, technology and society;
2. Understand boundaries and limitations of science;
3. Achieve scientific attitudes, integrity, values and desirable attributes;
4. Achieve skills in using scientific inquiry and problem-solving processes (IPST, 2003: 36).

Additionally, students should know that natural phenomena generally have consistent patterns and can be explained and tested by data and instruments. They also should be able to use scientific processes and scientific attitudes in acquiring knowledge and solving problems (IPST, 2003: 6).

2.3 Teaching and Learning Process of the Nature of Science

This Nature of Science and Technology content strand has been designed to be the standard core content strand for the learning process. The learning process of this strand should emphasize the inquiry process of gaining knowledge; the problem-solving process; the nature and limitations of science; and attitudes, moral principles, ethics, and values. Learners should be engaged in various practical learning activities of Science which lead them to a body of knowledge. Students should also participate in at least one science project for each stage (IPST, 2003: 30).

2.4 Standards for Teachers of the Nature of Science

IPST has set the Standards for Thai science teachers in teaching Science (IPST, 2003: 19). The first standard is The Nature of Science and Technology which requires the teacher to:

- understand the Nature of Science and Technology in its content and knowledge according to curriculum;
- understand ideas about the inquiry process and the problem-solving process;
- be able to use knowledge and understanding in generating learning experiences with meaningful science content for learners.

As seen from the Thai science standard documents, Thai teachers and students, like teachers and students in other countries, are required to have an adequate understanding of the Nature of Science. These standard documents should be implemented practically in order to achieve the aims of Thai national education. Thus, this research will emphasize and implement the standards recommended in these documents as the framework and goals of teacher development.

Philosophical Perspectives on the Nature of Science

In the three decades from 1960, many science educators have encouraged the promotion of the teaching and learning of the Nature of Science (Robinson, 1968; Moore and Sutman, 1970; Lederman, 1992; McComas *et al.*, 1998; Hand *et al.*, 1999). By this promotion, the contemporary view of the Nature of Science has been advocated extensively. Many researchers and educators argue for this contemporary view against the traditional view of the Nature of Science for effective science instruction. They claim that teachers and students should construct their understanding of the contemporary view beside the traditional view which is often stated as misconceptions (Munby, 1983; Abell and Smith, 1994; Clough, 1997;

Hammerich, 1998; Haidar, 1999). In order to clarify these two opposing views, the philosophical backgrounds of these views need to be discussed.

1. Traditional View of the Nature of Science

The traditional view relied heavily on two philosophical perspectives, the realist view of scientific theories and explanations, and the empiricist view of scientific knowledge and knowledge development.

According to the first philosophical view, realism, “scientific theories and explanations are taken to be true descriptions of the world” (Munby, 1983: 150) or at least approximately true (Nagel, 1961; Hung, 1997). They have high explanatory power and predictive power. They are likely to refer to real entities or to present real pictures of the world more accurately than our commonsense pictures (Hung, 1997). By this view, scientific theories could be evaluated under the light of empirical evidence as true or false (Nagel, 1961). Thus, the old theories which were proved untrue are usually inferred as being false theories and useless for scientists (Haidar, 1999). Additionally, scientific constructs, e.g. atom, are supposed to be true as physical reality (Nagel, 1961; Munby, 1983).

For scientific knowledge and knowledge development, empiricism claims “the power of senses” (sensory organs) as “collecting devices in acquisition of knowledge”, and “sense experience as the only source of knowledge” (Hung, 1997: 261 and 264). In this view, scientific knowledge, e.g. facts, law, and theories, are supposed to already exist in nature and scientists discover them by using scientific methods for producing a body of knowledge (Hammerich, 1998). The scientific methods used by scientists according to the empiricist view are usually based on Francis Bacon’s scientific method as an inductive method and Karl Popper’s hypothetico-deductive method. By these methods, scientific inquiry begins by observation and/or formulating an hypothesis and moves through classification, generalization, testing, and/or deducing and testing the empirical consequence from the hypothesis. These methods are a step-by-step process which could guarantee the

accuracy of scientific knowledge as representing the truth of natural world (Hung, 1997; Haidar, 1999). This traditional view of the Nature of Science concepts can be represented by many statements included in the Table 2.1, below.

Table 2.1 Traditional View of the Nature of Science

Nature of Science Aspects	Traditional View
Scientific Theories	<ul style="list-style-type: none"> • Scientists discover theories, because the theories are there in nature and scientists just have to find them. • Old theories are those which had been proven untrue, and are of no use to scientists. • A theory is a hypothesis that has been proven to be correct, because a hypothesis must be subjected to empirical test and if proven true it becomes a theory.
Scientific knowledge	<ul style="list-style-type: none"> • Scientific models (e.g. the model of the atom and neurological cell) are copies of reality, since they describe reality as it is. • Scientific laws can be proven to be absolutely true. • Scientific knowledge corresponds directly to reality. • Scientific knowledge is formed only through scientific means. • Scientific knowledge is generated first only through observations.
Development of Scientific Knowledge	<ul style="list-style-type: none"> • A scientist evaluates scientific claims exclusively through empirical evidence. • There is a single method to perform science that is the scientific method • The scientific method is a step-by-step process. • The use of the scientific method is necessary to discover and validate theories. • Scientists discover scientific laws, because the laws are there in nature and scientists just have to find them.
Scientists' Characteristics	<ul style="list-style-type: none"> • A scientist is someone who is objective and open-minded in all of his/her acts. • A scientist strives to discover the absolute truth.

Source: Adapted from Haidar (1999: 821-822)

2. Contemporary View of the Nature of Science

The opposing contemporary view relies heavily on two philosophical perspectives; the instrumentalist view of scientific theories and explanations, and the constructivist view of scientific knowledge and knowledge development.

Instrumentalism considers scientific theories and explanations as devices for understanding the world or “instruments for ordering perceptions” (Munby, 1983: 150; Hung, 1997). As Nagel (1961: 129) explained, “Theories are primarily logical instruments for organizing our experience and for ordering experimental laws”. Scientific theories are linked to mathematical symbols for their use in calculation, explanation, or prediction. These symbols or scientific models are only the instruments for scientific explanations which may not represent the reality (Hung, 1997) or absolute truth (Tobin and Tippins, 1993). From this point of view, scientific constructs, e.g. atoms, are “postulated entities” (Munby, 1983: 150) or “mental constructs” (Hung, 1997: 213). Additionally, scientific theories can not be characterized as either true or false. However, they can be judged according to their usefulness or viability and substantial evidence (Nagel, 1961; Hung, 1997). Thus, old theories or untrue theories, while still having value for scientists, can be changed and replaced by new theories which have more substantial evidence (Hung, 1997; Haidar, 1999).

Constructivism claims that the development of scientific knowledge is “a set of socially negotiated understandings of the events and phenomena that comprise the experienced universe” (Tobin and Tippins, 1993: 4). Scientific knowledge is constructed by scientists, and is not separated from them. This knowledge must be accepted by the scientific community as viable knowledge under empirical evidence and consistent with other understandings and experience. Thus, scientific knowledge is tentative and changeable and there is no one fixed set of steps of scientific method which guarantee the accuracy of knowledge as absolute truth. Scientists can adjust their methods of inquiry to gather their own valid results. Scientific knowledge and methods of scientific inquiry are varied according to the changes in the purposes of society and individuals (Tobin and Tippins, 1993; Haidar, 1999). This contemporary view of the Nature of Science concepts can be represented by many statements in Table 2.2, below.

Table 2.2 Contemporary View of the Nature of Science

Nature of Science Aspects	Contemporary View
Scientific Theories	<ul style="list-style-type: none"> • Scientists invent theories, because theory invention comes from the mind. • Theories fit within certain paradigms; hence if they are older or out dated, they can still be helpful to scientists in informing scientific thinking. • A theory is validated by its connection to other theories generally accepted within the scientific community.
Scientific knowledge	<ul style="list-style-type: none"> • Scientific models do not describe reality as it is. They are scientists' ideas or educated guesses, because scientists cannot see the real thing. • Scientific laws are only scientists' best attempt to explain a part of nature. • Scientific knowledge is our understanding of reality, not reality as it is. • Scientific knowledge is formed through scientific and non-scientific means. • Scientific knowledge might also be generated through imagination or creativity.
Development of Scientific Knowledge	<ul style="list-style-type: none"> • A scientist does not need to use empirical evidence exclusively; he/she may use imagination or creativity. • There is no single method to perform science. There are other methods, e.g. creativity, imagination and originality. • Scientists do not necessarily have to follow the sequence of the scientific method. • Scientists use several methods according to circumstances. The scientific method is only one of those methods. • Scientists invent scientific laws. Scientists do not invent what nature does, but they invent the laws, which describe what nature does.
Scientists' Characteristics	<ul style="list-style-type: none"> • A scientist is influenced by many factors, e.g. previous knowledge, logic and social factors. • A scientist works within the scientific community to find the best way to explain parts of nature.

Source: Adapted from Haidar (1999: 821-822)

These two different perspectives on the Nature of Science also consider the role of science teachers differently. In the traditional view, the teacher's role is to organize and transfer the facts of scientific content to students. The contemporary view claims that science teachers should help students construct their understanding

of scientific concepts by emphasis on the process of discovery rather than the accumulation of scientific facts (Hammerich, 1998).

3. Some Other Misconceptions of the Nature of Science

There are other misconceptions which have no dealing with these two philosophical perspectives. These misconceptions are held by teachers and students who view the Nature of Science differently from how science does, but these conceptions do not come from the philosophical perspective of the traditional view of science.

For example, the confusion between the definitions of science and technology, where science is equated with technology (Clough, 1997), and the confusion about some terms of scientific method and scientific knowledge which are used in science and in daily life or school life e.g. theories, laws, experiments, hypotheses, observations, and inferences illustrate these misconceptions (Solomon, Scott and Duveen, 1996; McComas, 1998; Akerson *et al.*, 2000).

These misconceptions are also a concern for science educators and researchers as they have been integrated into the research studies of teacher and student understandings of the Nature of Science (Solomon *et al.* 1996; Akerson *et al.* 2000).

Generally, these two philosophical perspectives, traditional and contemporary views of science, are underpinning an individual's understanding of the Nature of Science. This understanding can be represented by the various statements of conception in Tables 2.1 and 2.2. Thus, the conceptions of the Nature of Science can be categorised into three possible groups; based on traditional views, based on contemporary views, and based on a mixture of traditional and contemporary views. Additionally, the conception of the Nature of Science can also be categorized into misconception, naïve view, and appropriate conception of the Nature of Science, for the conception which is not related to the philosophical perspectives (Abd-El-Khalick and BouJaoude, 1997; Haidar, 1999).

These definitions give criteria for this study for use in identifying participant teachers' understanding of the Nature of Science in their conceptions of the Nature of Science.

Elements of the Nature of Science

In order to clarify the aspects of the Nature of Science which teachers should understand for their teaching, a range of ideas needs to be taken into account. There are three main areas of literature that provide information about the elements of the Nature of Science. These areas are:

1. Consensus and debate about the Nature of Science among philosophers of science and science educators;
2. Assessment criteria for conceptual aspects of the Nature of Science from assessment instruments; and
3. Elements of consensus about the Nature of Science from international science education standards.

1. Consensus and debate about the Nature of Science

Among philosophers of science and science educators, there are arguments about statements which really represent the characteristics of the Nature of Science. There is agreement on some issues of the Nature of Science, while other issues are still debated. Eflin, Glennan and Reisch (1999: 108-109) have identified some major areas of consensus and dissent. There are four areas of consensus and two areas of dissent.

1.1 Areas of consensus compose of:

- 1) The main purpose of science is to acquire knowledge of the physical world;
- 2) There is an underlying order in the world which science seeks to describe in a maximally simple and comprehensive manner;

- 3) Science is dynamic, changing, and tentative;
- 4) There is no one single, scientific method.

1.2 Areas of dissent compose of:

- 1) The generation of scientific knowledge depends on theoretical commitment and social and historical factors;
- 2) The truth of scientific theories is determined by features of the world which exist independently of the scientist.

It is recommended that teachers should have an understanding of these areas and use them to enhance students' understanding of the Nature of Science. Teachers can also teach students about debated issues in philosophy of science such as unity of science versus disunity of science, realism versus instrumentalism, practice and experimentation versus theory, and feminist philosophy of science. By teaching about these through scientific practice and history of science, students will see the complexity of science (Eflin *et al.*, 1999).

2. Assessment criteria for conceptual aspects of the Nature of Science

Despite the consensus and dissent over tenets from philosophers and educators, another group of resources of information for the important aspects of the Nature of Science which teachers should know can be gained from the assessment criteria of various Nature of Science instruments.

Lederman *et al.*, (1998: 332) reviewed and critiqued various Nature of Science assessment instruments which have been used since the 1960s. They emphasized that “most of the instruments addressed only certain aspects of the Nature of Science”. Thus, it should be noted that these aspects of the Nature of Science have provided consistent findings which had influence on the aims and objectives of the Nature of Science teaching and teacher development. These research findings have been used to advocate the Nature of Science standards published in *Benchmark for*

Science Literacy, Standards for Science Teacher Preparation, and Science for All Americans (AAAS, 1993 and 1994; NSTA, 1998).

There are several aspects of the Nature of Science which are generally emphasized by assessment instruments. Some of their assessment criteria for concepts of the Nature of Science are shown in Tables 2.3 and 2.4, below. The selection of these assessment instruments was based on instruments which had been mentioned previously in the research review of Lederman *et al.* (1998).

Table 2.3 Conceptual Areas of the Nature of Science in Assessment Instruments emphasizing a Specific Aspect

Nature of Scientific Knowledge Scale (NSKS)	Conceptions of Scientific Theories Test (COST)	Nature of Science Survey
A six-factor or six-subscale model of the Nature of Science	Aspects of scientific theories	A different aspect of tentativeness in scientific knowledge
Scientific knowledge is; 1. Amoral, 2. Creative, 3. Developmental, 4. Parsimonious, 5. Testable, 6. Unified.	1. Ontological implications of theories 2. Testing of theories 3. Generation of theories 4. Choice among competing theories	1. The use of human creativity & imagination in the development of scientific knowledge 2. The subjectivity resulting from scientists' background experiences, knowledge, & scientific paradigms 3. The difference between scientific theory & law 4. The importance of both observation & inference to the development of scientific knowledge 5. The empirical basis of scientific knowledge

Source: Lederman *et al.* (1998), and Lederman (1999)

Table 2.4 Conceptual Areas of the Nature of Science in Assessment Instruments
emphasizing Many Aspects

Test on Understanding Science (TOUS)	Nature of Science Test (NOST)	Views on Science-Technology-Society (VOSTS)	Nature of Science Scale (NOSS)
1. Understanding the scientific enterprise 2. The scientist 3. The methods & aims of science 3.1. Generalities about scientific methods 3.2. Tactics and strategy of science 3.3. Theories & models 3.4. Aims of science 3.5. Accumulation & falsification 3.6. Controversies in science 3.7. Science & technology 3.8. Unity & interdependence of the sciences	Components of the Nature of Science 1. Assumptions of science 2. Products of science 3. Processes of science 4. Ethics of science	VOSTS conceptual scheme <i>Definitions</i> 1. Science and Technology <i>External Sociology of Science</i> 2. Influence of Society on Science/Technology 3. Influence of Science/Technology on Society 4. Influence of School Science on Society <i>Internal Sociology of Science</i> 5. Characteristics of Scientists 6. Social Construction of Scientific Knowledge 7. Social Construction of Technology 8. Nature of Scientific Knowledge	Eight assertions in the model of the Nature of Science 1. The fundamental driving force in science is curiosity concerning the physical universe. 2. Science is a dynamic, on-going activity, rather than a static accumulation of information. 3. Science aims at ever-increasing comprehensiveness & simplifications using mathematics as a simple, precise method of stating relationships. 4. There is no one scientific method, but as many methods as there are practitioners. 5. The methods of science are better characterized by some value-type attributes than by techniques. 6. A basic characteristic of science is faith in the susceptibility of the physical universe to human ordering & understanding. 7. Science has a unique attribute of openness, both of mind & of the realm of investigation. 8. Tentativeness & uncertainty are characteristics of all science.

Source: Aikenhead and Ryan (1992), and Lederman *et al.*, (1998)

From the tables, there are two main kinds of instruments classified according to their focus. The first group of instruments focuses on only some specific aspects of the Nature of Science (Table 2.3); NSKS focuses only on characteristics of scientific knowledge; COST focuses on characteristics of scientific theories; and Nature of Science Survey focuses on the tentativeness of scientific knowledge. The second group of instruments focuses on many aspects of the Nature of Science such as TOUS, NOSS, VOST, and NOST (Table 2.4).

As can be concluded from the various instruments as seen in the tables, the main aspects of the Nature of Science which they generally emphasized are:

- 1) **Definition of science and aims of science:** includes unity and interdependence of the sciences;
- 2) **Characteristics of scientific knowledge:** includes characteristics of theory and model, tentativeness and uncertainty;
- 3) **The development of scientific knowledge/ Process of science:** includes characteristics of scientific inquiry and methods of science;
- 4) **Characteristics of scientists:** includes scientific attitude;
- 5) **Interrelation between science, technology and society:** includes influence of science, technology and society on each other, social construct of scientific knowledge, and understanding of scientific enterprise, and ethics of science.

Thus, it is important for teachers to know and understand all of these five main aspects of the Nature of Science found in an analysis of the assessment criteria.

3. Elements of consensus about the Nature of Science from International Science Education Standards

The last and most important group of resources to find out appropriate elements of the Nature of Science for teachers which could be implemented in their teaching context is the science education standards documents.

Among the various standards documents of many countries, the consensus statements and assumptions of the Nature of Science can be found. McComas and Olson (1998) have extracted statements which are elements of the Nature of Science from discrete sections or chapters of eight international science education standards documents including USA, Australia, England/Wales, New Zealand, and Canada. They found about thirty consensus statements and assumptions which could be categorized into four main groups related to four disciplines; philosophy of science, sociology of science, psychology of science, and history of science. Table 2.5 shows some of the statements and assumptions according each group.

Table 2.5 Consensus Statements and Assumptions from International Science Standards Documents

Related Disciplines	Statements & Assumptions
Philosophical insights	<ol style="list-style-type: none"> 1. Scientific knowledge is tentative. 2. Science relies on empirical evidence. 3. Science is an attempt to explain phenomena.
Sociological insights	<ol style="list-style-type: none"> 1. All cultures contribute to science. 2. Scientists make ethical decisions. 3. Scientists require peer review.
Psychological insights	<ol style="list-style-type: none"> 1. Observations are theory-laden. 2. Scientists must be open to new ideas. 3. Scientists must be intellectually honest.
Historical insights	<ol style="list-style-type: none"> 1. Change in science occurs gradually. 2. Science has global implications. 3. Science is part of social traditions.

Source: Adapted from McComas and Olson (1998: 44-48)

Although the consensus statements and assumptions in the work of McComas and Olson were categorized by the related disciplines, these statements and assumption could also be categorized into five groups of elements of the Nature of Science derived from the Nature of Science assessment instruments in the previous section. Table 2.6 shows example of the statements and assumptions categorized into these five aspects.

Table 2.6 Consensus Statements and Assumptions in the Nature of Science
Conceptual Schemes Categories

Aspects of the Nature of Science	Statements & Assumptions
1. Definition of science & aims of science	1. Science is an attempt to explain phenomena. 2. Science is human endeavor. 3. Science aims to be objective.
2. Characteristics of scientific knowledge	1. Scientific knowledge is tentative. 2. Science relies on empirical evidence. 3. Scientific knowledge is based on observation.
3. The development of scientific knowledge	1. Observations are theory-laden. 2. There are many ways to do scientific investigations. 3. Science relies on logical arguments.
4. Characteristics of scientists	1. Scientists must be open to new ideas. 2. Scientists must be intellectually honest. 3. Scientists require replicability.
5. Interrelation between science, technology & society	1. All cultures contribute to science. 2. Science is part of social tradition. 3. Technology has impacted science.

Source: Adapted from McComas and Olson (1998: 44-48)

Thus, it is shown that the five main aspects of the Nature of Science concluded from the assessment instruments' criteria cover all the aspects of the Nature of Science found in consensus statements and assumptions among international science standards documents. In other words, consensus statements and assumptions among international science standards documents generally emphasize these five main aspects of the Nature of Science. This confirms the importance of teachers having an understanding of the Nature of Science in these five main aspects.

In Thai science standards documents, elements of the Nature of Science identified by IPST can be categorized into three of those five main aspects; the development of scientific knowledge, the characteristics of scientific knowledge, and interrelation between science, technology and society (IPST, 2003: 74).

3.1 The development of scientific knowledge composes of three statements as below.

1) Scientific knowledge has been gained by human attempts to use the scientific process in scientific inquiry; and to solve problems by observing, investigating, researching and data gathering systematically. Thus, the body of knowledge is increasing all the time.

2) Scientific knowledge and process have been successful for a long time.

3) Science is a result of the individual's knowledge development.

3.2 The characteristics of scientific knowledge compose of two statements as below.

1) Scientific knowledge should be able to be explained and examined.

- It should be used in reference both in support and debate when discovering new data and evidence.

2) Scientific knowledge is changeable

- There could be contradictions from the same data because scientists interpret data in different ways and with different ideas.

3.3 Interrelation between science, technology and society compose of two groups of statements as below.

1) Science and Society

- Everybody in every part of the world can participate in science.

- The communication and publication of scientific data for analytical and critical thinking increases scientific knowledge ceaselessly, and affects humanity in society and the environment.

- Research and use of scientific knowledge must be within the limitations of moral principles and ethics which are accepted by society and help maintain environment everlastingly.

2) Science and Technology

- Scientific knowledge is the important foundation of technology development.
- Technology is the process in any work or process of developing and improving products by using scientific knowledge cooperating with other disciplines, skills, experiences, imagination, and creativities of humanity.
- Technology relates to resources, processes, and management systems.
- Technology must be used to advantage society and environment.

The Nature of Science Conceptual Scheme

It can be concluded that the elements of the Nature of Science which should be contents of the Nature of Science for teachers and students in teaching contexts consist of the five main aspects: definition of science; characteristics of scientific knowledge; development of scientific knowledge; characteristics of scientists; and interrelation between science, technology, and society.

For this research, the components of each element of the Nature of Science are identified and shown in the form of the Nature of Science conceptual scheme which follows. The numbering system of a five-digit code is used in this scheme (Aikenhead and Ryan, 1992). This is for the development of question items of the Nature of Science Questionnaire and for the interpretation of responses. This scheme is presented in Table 2.7 below.

Table 2.7 The Nature of Science Conceptual Scheme

The Nature of Science Conceptual Scheme	
<u>1. Definitions of science</u>	
01.	Defining science (e.g. Science as both body of knowledge and process to explain about natural phenomena)
02.	Defining major disciplines in science (e.g. pure science, applied science)
03.	Interdependence of science and other disciplines (e.g. relationship between science and mathematics, language, art)
<u>2. Scientific knowledge</u>	
01.	Source of scientific knowledge (e.g. questioning natural phenomena, scientific approach to investigations)
02.	Nature of scientific knowledge
.1	Validity of scientific knowledge (e.g. knowledge about phenomena; knowledge based on observations and measurements; collecting accurate data; and careful analysis, knowledge which is checked and approved by other scientists)
.2	Kinds of scientific knowledge (e.g. facts, concepts, principles, laws and theories)
.3	Specific characteristics of scientific knowledge (e.g. tentative, empirical, theory-laden, perceptual bound/relative-absolute, inferential, imaginative and creative, objective, universal/uniformitarian, precise and uncertain, logical/rational argument, sceptical)
<u>3. Development of scientific knowledge</u>	
01.	Scientific world view and basic assumptions of nature
.1	The world is understandable.
.2	The universe occurs in consistent patterns that are comprehensible through careful and systematic study.
.3	People can discover patterns in all of nature by use of intellect and aid of instruments.
.4	Science cannot provide complete answers to all questions.
.5	Science has inherent limitations.
02.	Scientific method and process (e.g. general scientific methods; questioning, data gathering and analysis, conclusion, and communication)
03.	Characteristics of scientific inquiry
.1	No one way to do science and many ways to do scientific investigations
.2	No universal step-by-step scientific method
.3	Attempts to explain and predict phenomena (e.g. involving the process of formulating and testing hypotheses or theories, examining of evidence, and generating new questions)
.4	Logical-reasoning, imagination, and curiosity are attributes of scientific inquiry.
.5	Communication of scientific results, attributes of scientific inquiry (e.g. new knowledge must be reported clearly and openly)
04.	Scientific process skills
.1	Scientists use science process skills to accomplish their work (e.g. observing, measuring, inferring, communicating, predicting, etc.)

Table 2.7 (Continued)

The Nature of Science Conceptual Scheme	
4.	<u>Characteristics of scientists and scientific attitudes (Habits of Mind)</u>
	01. Curiosity (e.g. scientists thrive on curiosity)
	02. Perseverance (e.g. scientists require replicability)
	03. Reasoning (e.g. scientists are sceptical about all new theories)
	04. Trustworthiness (e.g. scientists must be intellectually honest)
	05. Circumspection (e.g. scientists require accurate record keeping)
	06. Broad-mindedness (e.g. scientists must be open to new ideas, scientists work collaboratively and require peer review)
5.	<u>Interrelation between science, technology, and society</u>
	01. Interrelation between science and technology (e.g. Science and technology impact on each other, technology draws on science and contributes to science)
	02. Interrelation between science and society
	.1 Science is part of intellectual, social and cultural traditions (e.g. scientific ideas are affected by their social and historical milieu, science is a human endeavour, scientists participate in public affairs both as specialists and as citizens)
	2 The history of science reveals both an evolutionary and revolutionary character (e.g. Science builds on what has gone on before).
	.3 People from all cultures contribute to science.
	.4 Science is a complex social activity and is conducted in various Institutions.
	.5 There are generally accepted ethical principles in the conduct of science (e.g. scientists make ethical decisions).

Teaching Approaches for the Nature of Science

1. Generally agreed characteristics for the Nature of Science instruction

To promote student understanding of the Nature of Science, there are several characteristics agreed on which teachers should consider to ensure the effectiveness of their instruction of the Nature of Science. These areas can be categorized into four main groups:

1.1 Explicit instructional aims and objectives for the Nature of Science;

1.2 Explicit and reflective Nature of Science instruction as integral part of science classes;

1.3 Contemporary view of the Nature of Science and constructivist view of learning;

1.4 Instructional factors which affect the Nature of Science instruction.

1.1 Explicit instructional aims and objectives for the Nature of Science

In order to promote instruction in the Nature of Science, the instructional aims and objectives should be set and considered explicitly on every level of curriculum implementation (Robinson, 1968; Lederman, 1998; 1999). The importance of the Nature of Science instructional aims and objectives should also be considered as “permeat[ing] all aspects of curriculum and instruction” (Lederman, 1998: 8).

This is because an explicit understanding of the Nature of Science is considered to be an essential component of the scientific literacy recommended in contemporary goals of science education. This understanding will enhance “the public understanding of science” (Driver *et al.*, 1996: 9). Students who have a public understanding of science would have:

....an appreciation of both the power and the limitations of scientific knowledge claims and an appreciation which is necessary for dealing appropriately with the products of science and technology as informed citizens who can participate fully in a modern democracy (Driver *et al.*, 1996: 1).

Teachers should be concerned that the understanding of the Nature of Science is the ideas that students have about science itself which is distinct from ideas about the natural world (scientific knowledge, concepts or principles) (Driver *et al.*, 1996). These ideas are considered as the students’ epistemological beliefs which affect their mental and physical learning of Science. For example, “students who recognize that scientific theories will inevitably change over time are more likely to evaluate theories with a critical eye” (Ormrod, 2000: 376-377).

Understanding of the Nature of Science is an important *cognitive* instructional outcome rather than an *affective* instructional outcome (Lederman, 1998: 7). As Osborne (1998 cited in Newton, 2000: 28) argued, an understanding of the Nature of Science is the *ability* to “assess the level of certainty of scientists’ claims... appraise risks... understand how scientists produce reliable knowledge; distinguish correlations from causes... and translate and interpret common scientific reports presented by the media”.

Teachers should recognize that these outcomes should be planned and considered during the development of every instructional unit, lesson, and activity and should also be explicitly taught and assessed during their implementation (Lederman, 1998; 1999).

Generally, there are two opposite views of any serious intellectual or epistemological questions or issues about the Nature of Science (Matthews, 1997). The Nature of Science itself is complicated and tentative as seen from its philosophical underpinning. No one could claim to have “knowledge of science as it really is” (Cleminson, 1990: 437; Akerson *et al.*, 2000). Thus, the purpose of teaching and learning about the Nature of Science should not be for teachers to transmit their views of any aspects of the Nature of Science to make their students agree with them and think as they think, but to have their students think, understand, and become interested in aspects of the Nature of Science (Matthews, 1997).

There is also the argument that the purpose of a science class should be to develop, in students, “intellectual autonomy” (Matthews, 1997: 311) or “intellectual independence” (Driver *et al.*, 1996: 15). By learning the Nature of Science, students should understand why scientific ideas and theories are reasonable rather than simply accept them and should be able to give adequate reasons and justify what they believe (Matthews, 1997). Students also should have the skill of scientific reasoning which emphasizes developing an understanding of the nature of scientific knowledge and of the purpose of science (Driver *et al.*, 1996: 16).

Thus, the role of teachers is to provide students with “all the resources necessary for judging the truth of knowledge independently of other people” (Driver *et al.*, 1996: 15) “without ... overwhelming” them (Matthews, 1997: 311).

1.2 Explicit and reflective Nature of Science instruction as integral part of science classes

There are several points of concern which science educators have about the instruction of the Nature of Science. Teachers should consider these when they design and implement their Nature of Science instruction.

1.1.1 The concepts of the Nature of Science should be spread over a science course. This is because at primary and secondary school level there is no special epistemology (Nature of Science) course (Meyling, 1997).

1.1.2 Learning by doing science and practical work - engaging in discovery methods; engaging in hands-on, inquiry-based activities and/or process-skills instruction; having simple experience in authentic scientific inquiry; engaging in packaged laboratory activities; or using cookbook laboratory activities - are *insufficient* for students to improve their understanding of the Nature of Science (Robinson, 1965; Hodson, 1985; Lederman, McComas, and Matthews, 1998).

This concern has been raised about the assumption that identifies the Nature of Science with a method of enquiry and views science as “a powerful, and quite general, method of enquiry which can be learnt and then used in a wide range of other contexts, both scientific and non-scientific” (Driver *et al.*, 1996: 17). This assumption also claims that by learning and practicing scientific process skills, students “will be able to transfer them to new situations and they will thus come to appreciate the power and utility of the scientific method of enquiry” (Driver *et al.*, 1996: 17). It has been argued by many science educators. There are at least two points which have been questioned about this assumption.

The first point is about the philosophical perspective underpinning the process approach or discovery method for teaching Science. Science educators claim that these approaches could not present the appropriate characteristics of the nature of scientific inquiry. For example, the discovery method relies heavily only on inductive inference (Hodson, 1985), the process approach lacks a portrayal of the importance of the conceptual framework that is guiding empirical investigation (Driver *et al.*, 1996). Thus, students may have inappropriate views of the Nature of Science.

The second point is a concern about the ability of learners to generate or relate the conceptions about the Nature of Science from learning through doing science or inquiry activities and to apply these conceptions to their daily lives. Hodson (1985: 42) had argued that students may be able to discover the simple information from discovery activities, but they could not “discover the theoretical framework with which to classify and explain their findings. This explanatory framework is provided by the teacher”. Driver *et al.* (1996) also argued that the empirical evidence to support the idea that general process skills could be transferred to become public understanding of science is insufficient. The public understanding of science is more sophisticated than just to be taught implicitly in the process approach. These arguments have been confirmed by the empirical evidence of Meichtry (1992) who found that students were not be able to make the connections between their science content and processes they had learnt to the aspects of the Nature of Science by themselves when the curriculum and teachers did not directly relate these for them.

As a result of a literature review of the implicit approach for teaching the Nature of Science which included teaching strategies of learning by doing science, hands-on, inquiry-based activities and process-skills instruction together, Lederman (1998: 7) concluded that; “We should no longer assume that students will come to understand the Nature of Science or scientific inquiry as a by-product of ‘doing’ science-based or inquiry activities”. In addition, Lederman and Abd-El-Khalick (1998: 83) argued that “Students could not come to understand the Nature of Science simply through the performance of scientific inquiry and/or investigation”.

1.1.3 Many science educators have noted that students need to engage in activities which explicitly reflect on the conceptions of the nature of scientific inquiry in order to develop understanding of the Nature of Science (Hodson, 1985; Meichtry, 1992; Lederman, 1998; Lederman, McComas, and Matthews, 1998).

Concepts about the Nature of Science should be addressed explicitly during science instruction and should have status equal to science subject matter. It should also be considered as the context for science subject matter (Lederman, 1998).

According to this argument for explicit instruction of the Nature of Science, the learning strategies based on learning by doing science, hands-on, inquiry-based instruction and other practical works are still utilized. However, to extend their efficiency, these activities should be incorporated with some activities or discussions which promote epistemological or metacognitive reflection. Students are unlikely to make the connections between science-subject content and concepts of the Nature of Science by themselves. Thus, teachers should make a connection by explicitly relating the science-subject content and elements of the Nature of Science for them (Meichtry, 1992; Meyling, 1997; Michaels and Bell, 2003). This incorporation focuses on explicitly pointing out and reflecting on the aspects of the Nature of Science that are highlighted during practical work. Students would have a chance to discuss the implications of such aspects for the way they view scientists, scientific knowledge, and the practice of science (Lederman, 1998).

There are a number of the teaching and learning models, activities and instructional materials designed based on this idea of explicit and reflective discussion of the Nature of Science. Some of them are summarized below.

a) Explicit and Reflective Activity-Based Approach – teaching by various activities and games designed for teaching about crucial aspects of the Nature of Science explicitly and getting students thinking and reflecting on their views of science. Six examples of these activities are presented below.

(1) *A set of activities* - teaching by the activities designed for explicitly teaching about crucial aspects of the Nature of Science e.g. distinction between observation and inference, appreciation of the tentativeness of scientific knowledge and the role of creativity in science (Lederman and Abd-El-Khalick, 1998; Akerson *et al.*, 2000).

(2) *Explicit epistemological teaching* - teaching by using ‘epistemological reflection’ to change epistemological conceptions of students by explicitly teaching epistemology in a science course (Meyling, 1997).

(3) *The card exchange and the card sorting* - teaching by using card exchange or card sorting games for introduction of philosophy of science. The Nature of Science statements are placed on each card in the set. Students would evaluate their cards according to their degree of affirmation. By this game, students would begin to recognize their various views of science and what science is all about (Bell, 1993; Cobern and Loving, 1998; Gess-Newsome, 2002).

(4) *Learning by designing and Heuristic-directed theory development* - teaching by engaging students in theory development and providing opportunities to reflect on the Nature of Science (Jansen and Voogt, 1998).

(5) *Scientific Theory Profile (STP)* - teaching by using the profile that represents the various positions on scientific theories and giving students opportunities to discover and adjust their own view to become more balanced (Loving, 1991; 1998a).

(6) *“If-And-Then-Therefore” pattern* – teaching by using a scientific reasoning pattern to develop students’ theoretical reasoning ability in science and understanding of the Nature of Science (Lawson, 1999).

b) Nature of Science in the Context of Laboratory Activities and Experimental Work – teaching by engaging students to work in small research teams and develop experiments to investigate a particular question posed by the

instructor, selecting and using equipment by themselves, determining and justifying their data and interpreting results, and presenting these to the whole class after the lab experience, without confirmation whether their work was correct or not (open-ended inquiry laboratory activities). To elicit the aspects of the Nature of Science, journal writing to reflect student views of the nature of scientific process and post-lab discussion are used to discuss significant issues in the Nature of Science (Spears and Zollman, 1977; Clough, 1997, 1998; Tsai, 1999).

Teachers can also teach experimental work by engaging students to first work with the models of science in explaining and predicting scientific phenomena and then, to do the experiments to check whether their predictions work or not. Teachers can also use history of science and stories about science to teach about the development of scientific models which are being studied (Kipnis, 1998; Wellington, 1999).

c) Explicit and Reflective Inquiry-Oriented Instruction - teaching by using a method of inquiry teaching such as the learning cycle (Bianchini and Colburn, 1999), 5E learning cycle (National Academy of Science, 1998), a guided inquiry model (Khishfe and Abd-El-Khalick, 2002), or open-ended inquiry model with model-focused instruction (Cartier and Stewart, 2000) including the use of the Nature of Science activities e.g. cubes or science story telling, and extended discussion of the Nature of Science to give students opportunities to reflect on these activities and generate their understanding of the Nature of Science.

d) Teaching Controversial Issues, Science Stories, and Bad Science — teaching about some controversial issues such as scientific debate or disagreements about the applications of science, i.e. GM foods, nuclear energy and weapons, cloning of animals or humans; some stories of science; or historical cases that exemplify “bad science” (Sadler and Zeidler, 2003: 36).

Including these issues in teaching Science will make the science content more interesting and meaningful, portray the true Nature of Science,

develop important attitudes, skills and understanding of processes, develop critical reasoning skills and inspire critical inquiry.

These issues can be taught by using some practical classroom strategies e.g. critical questions and structured discussion with brainstorming, questionnaires, examining pictorial material, role play and simulation, and structured reading, listening, watching and writing of items involving some stories of science (Milne, 1998; Hand *et al.*, 1999; Wellington, 1999; Terrence, Young and Coleen, 2001; Oulton, Dillon and Grace, 2004).

Additionally, many science educators have suggested the integration of philosophical and historical studies of science within science courses for teaching concepts of the Nature of Science. They recommended that the philosophy and history of science can be taught as a component of science while learning scientific concepts (Manurl, 1981; Arons, 1988; Matthews, 1989; Bybee *et al.*, 1991; Solomon *et al.*, 1992; Kipnis, 1998; 1992; 2000). By studying these, students can learn about many aspects of the Nature of Science such as the nature of scientific methods (Hodson, 1985).

There are a number of teaching and learning models and their specific instructional materials for this historical approach, named by Ledeman (1998). Some examples of these models are historical case study (Cooley and Klopfer, 1963; Klopfer and Cooley, 1963; Gauld, 1993; Dawkins and Glatthorn, 1998; Nelson, Nickels and Beard, 1998; Seroglou, Koumaras and Tselfes, 1998; Abd-El-Khalick, 1999; Irwin, 2000), historical vignettes (Roach, 1992; Roach and Wandersee, 1995), historical investigative approach (Lawrenz and Kipnis, 1990; Kipnis, 1996; 1998), and Monk and Osborne's pedagogic model for incorporating the history of science (1997).

1.3 Contemporary View of the Nature of Science and Constructivist View of Learning

The contemporary view of the Nature of Science from the philosophical standpoint and the constructivist view of learning from the psychological standpoint are considered as the foundations of the rationale and aims of many science curricula with the contemporary national goal of science literacy (Meichtry, 1992; AAAS, 1994; Hand *et al.*, 1999). These two different perspectives had been considered and analysed for their correspondence and consonance by Cleminson (1990). Table 2.8 shows summarized assumptions comparing these two perspectives.

By these correspondent assumptions, the Nature of Science instruction seems to match the learning and teaching models based on a constructivist view of learning. The combination of these instructions could be made by teaching the concepts of the Nature of Science through the learning and teaching models based on a constructivist view as well as using a contemporary view of the Nature of Science to enhance conceptual change. It is believed that these will be the most effective instruction to help students to become scientifically literate (Cleminon, 1990; Clough, 1997; Monk and Osborne, 1997; Hammerich, 1998; Loving, 1998b; Ormrod, 2000).

Table 2.8 Consonant Assumptions of Contemporary View of The Nature of Science and Constructivist View of Learning

Contemporary view of Nature of Science	Constructivist view of learning
<p>1 Scientific knowledge is tentative and should never be equated with truth. It responses the consensus view among scientists at a particular time and so has only temporary status.</p>	<p>Knowledge of the physical world develops from birth. Concepts and theories are personally and socially constructed. Their status is temporary insofar as additional experience or instruction may modify such conceptions.</p>
<p>2 Observation alone cannot give rise to scientific knowledge in a simple inductivist manner. We view the world through theoretical lenses built up from prior knowledge. There can be no sharp definition between observation and inference.</p>	<p>These personally constructed views about the physical world affect our observations of that world. They act as our personal theoretical lenses and, as such, determine what, for us, counts as an observation and what counts as in inference.</p>
<p>3 New knowledge in science is produced by creative acts of the imagination allied with the methods of scientific inquiry. As such, science is a personal and immensely human activity.</p>	<p>Learning new scientific concepts involves more than the utilization of established methods of scientific inquiry. It requires ‘a theory change of the sort achieved by Galileo’. As such, it requires a creative act of the imagination.</p>
<p>4 Acquisition of new scientific knowledge is problematic and never easy. Abandoning cherished knowledge that has been falsified usually occurs with reluctance.</p>	<p>Learning new scientific concepts is problematic and never easy. Abandoning cherished knowledge, even as a result of exposure to science teaching, is difficult and may be done only superficially.</p>
<p>5 Scientists study a world of which they are a part, not a world from which they are apart.</p>	<p>We all have conceptions about our physical world, whether they correspond to those of formal science or not. As such, they necessarily have subjective meaning for us. Our world and our conceptions of that world are intimately connected.</p>

Source: Adapted from Cleminson (1990: 429-446)

Teachers can use the learning and teaching models based on a constructivist view of learning to help students restructure and change their naïve views of the Nature of Science by using “the instructional models which induce conceptual change” (Meichtry, 1992: 405). Teachers should assess students’ prior knowledge of the Nature of Science and use it as “a diagnostic tool to design instructional strategies” (Meichtry, 1992: 405). Students’ alternative frameworks, the ideas of “ascertaining the learner’s prior knowledge” and the “process of formative

assessment” should be taken into account in the teaching the Nature of Science with scientific concepts (Monk and Osborne, 1997: 412). Teachers should also consider using the epistemological questions of “how we know” in the teaching (Monk and Osborne, 1997: 414).

In order to change students’ misconceptions of the Nature of Science, Clough (1997) suggested an instructional course based on this constructivist view of learning which uses the approach of eliciting student’s views and reasoning, follows by discrepant events, reading articles, and class discussions throughout the course. He suggested two more ways to maintain pressure on student’s misconceptions of the Nature of Science in the context of learning science content. The first is using more open laboratory activities incorporated with journal writing and post-laboratory discussion. The second is encouraging students to critically analyze the reading assignments, historical anecdotes, and their science textbook on the portrayal of the Nature of Science. Additionally, the Nature of Science can be emphasized throughout practical science activities based on the Cortes’ Multicultural Empowerment Model and Wittrock’s Generative Science Teaching Model (Loving, 1998b).

Based on the view that scientific knowledge is socially constructed, validated, and communicated by scientific community, Driver *et al.* (1994) suggested that learning science involved both personal and social process. By the social constructivist view of learning, teacher has a role in providing “appropriate experiential evidence and to make the cultural tools and conventions of the science community available to students” (Driver *et al.*, 1994: 7). Students should have a chance to learn concepts, symbols, and conventions of the scientific community by involving in community of discourse or social interaction as well as in personal making sense of the newly introduced concepts. Students have interaction with teacher who introduces new ideas or culture tools and provides support and guidance for students to make sense of these by themselves.

1.4 Instructional Factors which affect the Nature of Science Instruction

In addition to the teaching and learning approaches used in the Nature of Science instruction, teachers should be concerned with some implicitly instructional factors which could affect their students' understanding of the Nature of Science.

1.4.1 Role of textbooks, curriculum materials and media

Science educators argued that language used in curriculum materials and media could implicitly convey views of science, such as instrumentalist or realist, to students (McComas *et al.*, 1998). The problem is that there is also inconsistency in how science is portrayed in textbooks. Lederman, McComas, and Matthews (1998: 507) note that:

Most texts briefly, and inadequately, discuss the Nature of Science in the opening chapter, and then portray science in a distorted, positivistic, and 'final form' fashion throughout the rest of the book.

1.4.2 Role of teacher's verbal behaviours or patterns in communicating or portraying the Nature of Science

Research found that students who learned with teachers who verbally portray science in a realist view tend to have a realist view of science. Thus, teacher's verbal behavior implicitly conveys a view of science and affects their student's construction of their conceptions of the Nature of Science (Lederman and Druger, 1985; Lederman, 1986; McComas *et al.*, 1998).

In summary, the Nature of Science could be taught based on the constructivist view of learning. Teachers have a role to elicit students' conceptions of the Nature of Science and facilitate movement from students' misconceptions or naïve views toward the correct scientific view. As well as appreciating the importance of the Nature of Science as the instructional cognitive learning outcomes, teachers should teach it as the context of science subject matter. In order to do this, teachers should

also consider generally agreed characteristics of the Nature of Science instruction which are included in Clough's points of concern.

1. Modeling behaviors, strategies, and language that reflect an understanding of the Nature of Science. For example, accurate usage of significant language in the social studies of science affects students' perceptions of the Nature of Science.

2. Addressing explicit and implicit view(s) of the Nature of Science portrayed in activities (lab or otherwise).

3. Evaluating textbooks, audiovisual materials, and other curriculum materials for their accuracy in portraying the Nature of Science.

4. Modifying curriculum materials and activities so they more adequately portray the Nature of Science.

5. Implementing timely historical examples that effectively convey a more accurate portrayal of the Nature of Science.

6. Ensuring that students have several experiences where they are *doing* science, and then *reflecting* on the process and what it implies about the Nature of Science.

7. Self-evaluating classroom performance as it pertains to an accurate portrayal of the Nature of Science.

8. Evaluating materials designed to assess student understanding of the social studies of science.

9. Integrating a variety of formative assessments to continually monitor students' conceptions of significant issues in the Nature of Science (Clough, 1997: 200).

These points of concern will be used as the framework in this research for studying and improving primary school teachers of Science's understanding of the instruction of the Nature of Science.

2. Teaching the Nature of Science in Lower Primary School

In order to make decisions on appropriate teaching activities for students in lower primary school level, teachers have to consider the characteristics of children's way of thinking. These characteristics differ based on children's mental development. In the early stage (5-7 years) students need to "carry out actions to see their results rather than think through them" (Harlen, 2002: 82). They look at things from only one point of view, focus on one aspect of an object or situation at a time, identify only parts of a sequence of events and have a limited idea of the cause of a particular effect (Harlen, 2002). Students in an older stage (8-10 years) can "begin to see a simple process as a whole" (Harlen, 2002: 84) and grasp a process of change and put it in sequence. They can consider more than two effects that may be needed in deciding the result of an action, can relate a physical cause to its effects and can see things from another's point of view. However, their thinking still has limits. They can think only on the familiar and have "no substitute for action and firsthand experience when new things are encountered". Their thinking is dependent on the strength of the visual impression. Additionally, "they may be able to investigate the effect of one variable but if there are two operating together it is unlikely that their effects can be separated" (Harlen, 2002: 85).

The appropriate science activities for students at the early stage can be simple activities based on using their sensory organs such as looking, handling, using other senses on material collected and displayed in the classroom; watching, standing and staring at things in their natural state in the immediate neighbourhood. They can do simple investigation such as classifying and identifying and exploring. The teacher can ask them to talk about what they have observed and can sometimes ask them to record it "in pictures and models and in words when they can discuss their ideas and try to think of explanations for things they have noticed" (Harlen, 2002: 83-84). The activities for older students can be more complex in process such as using "a wider range of objects and events to observe and to relate to their existing experience" (Harlen, 2002: 86); using tasks that require close observation of detail and sequence of events and a search for patterns or relations in observations. Teachers can use the investigation activities such as fair testing, exploring, classifying and identifying, with

students at this stage. Students can do some simple experimentations and investigations of the effect on some object or system of changing a variable systematically while keeping other things the same. They can also encounter the problems that demand fair comparisons between objects or materials. Teachers should encourage them to try to explain how things work and to find answers to their own questions by systematic and controlled investigation (Harlen, 2002).

To include the Nature of Science in lower primary school science teaching, Newton (2000) suggested that teachers should help their students to view science in a balanced way. Students should understand science as the processes of thinking and working, as the product which is a body of knowledge, and as people, since science is human enterprise which is relevant throughout their lives. The activities such as “work like a scientist” (Newton, 2000: 30) where students participate actively in the process of science can break down the naïve stereotypical images of science and scientists of primary school students. Teachers can also introduce the history of science to their students by the studying scientists’ lives. This can help by addressing some true stereotypes of scientists and the diversity of activities of science. Moreover, students at primary school level also have potential to have sensitive debate over the scientific issues or controversial issues related to social, moral and ethical dimensions. Teachers can use children’s books, stories and poetry to introduce such debate and lead to the discussion of ideas for experimentation, investigation, the validity of the evidence, and recognition and making choices of various values and beliefs (Newton, 2000).

Children at primary school level have limited ability to think about science, limited abstract and hypothetical reasoning capabilities and ability to separate and control variables. However, engaging students in simple experiments, besides only focusing on describing the natural phenomena, “can convey the message that science is an ongoing, dynamic process of unravelling the mysteries of our world” (Ormrod, 2000: 377). Importantly, teachers should provide some “considerable scaffolding” for students to conduct meaningful experiments and interpretation.

One of the scientific attitudes which should be emphasized to students at this level is “the respect for evidence” (Harlen, 2002: 78). As students tend to ignore evidence that contradicts their hypotheses and look for only evidence that confirms them, teachers should encourage students to look for evidence that both confirms and contradicts their hypotheses (Ormrod, 2000; Harlen, 2002). Teachers can ask students to keep several questions in mind such as “Am I seeing anything that supports my hypothesis? Am I seeing anything that contradicts my hypothesis?” (Ormrod, 2000: 379)

In conclusion, it is possible to teach the Nature of Science effectively at primary school level if teachers consider the characteristics of students’ ways of thinking based on their stages, the appropriate activities of science teaching related to students’ stages, the generally agreed characteristics of the Nature of Science instruction and some suggestions from science educators on the teaching of Nature of Science as reviewed above. Thus, in order to develop primary school teachers’ understanding and teaching of the Nature of Science, all of these characteristics of the Nature of Science instruction should be the message conveyed explicitly to teachers in the professional development program.

Attempts to Improve Teacher’s Understanding and Teaching of the Nature of Science

The teacher is a significant factor in promoting student understanding of the Nature of Science. The attempt to assess and improve teacher understanding of the Nature of Science in both concepts and instruction, is one of the major lines of research related to the Nature of Science (Lederman, 1992; Abd-El-Khalick and Lederman, 2000).

In order to develop the professional development program for promoting teacher understanding of the appropriate concept of the Nature of Science and their instruction, it is important to review:

1. Teacher understanding of the Nature of Science and their Nature of Science instruction;
2. The assumptions and guiding principles of teacher knowledge and development of the Nature of Science instruction;
3. Characteristics of effective programs for developing teacher understanding and teaching of the Nature of Science.

1. Teacher understanding and their instruction of the Nature of Science

1.1 Teachers' conceptions of the Nature of Science

Teacher understanding of the Nature of Science is generally limited, simplistic, unclear, and inadequate for teaching the Nature of Science according to the contemporary science curriculum. These inadequate conceptions are consistently found throughout many research studies either based on paper-pencil standardized instruments or qualitative research (Rampal, 1992; Abell and Smith, 1994; Lakin and Wellington, 1994; Ogunniyi *et al.*, 1995; Lederman *et al.*, 1998; Murcia and Schibeci, 1999; Akerson *et al.*, 2000; Eick, 2000; Gess-Newsome, 2002; Akerson and Abd-El-Khalick, 2003).

Both pre-service and in-service science teachers normally have similar views regarding the Nature of Science (Rubba and Harkness, 1993; Haidar, 1999; Tairab, 2001). In general, they hold a view of science that is positivist, naïve realist and inductivist, authoritative, and supports scientism (Rubba and Harkness, 1993; Abell and Smith, 1994; Tobin and McRobbie, 1997; Fysh and Lucas, 1998; Murcia and Schibeci, 1999). They tend to see science as searching for the truth of the world and rely heavily on objective scientific observation. Ideas reflect the scientists' personality and perception, and there is a lack of concern for the social aspects of science. Although they accept the uncertainty and change of scientific knowledge, they tend to view the scientific method as one fixed set of steps and universal. Scientific knowledge is induced from empirical or experimental foundations. Scientific knowledge could also be transferred from teachers to students (Tobin and McRobbie, 1997). These views are commonly called traditional views of science and

are compared to the contemporary views based on an instrumentalist and constructivist view of science. This traditional view of science is considered as inadequate in its conceptions of the Nature of Science (Pomeroy, 1993; Abd-El-Khalick and BouJaoude, 1997; Haidar, 1999; Murcia and Schibeci, 1999; Tsai, 2002).

It was found that among the scientists, secondary science teachers, and elementary teachers, the elementary teachers held the most appropriate views of the Nature of Science. Elementary teachers held less traditional views and a more non-traditional, contemporary view of science. The reasons suggested were that elementary teachers may have developed their alternative views of science from their views about children's learning, their own personal practice of teaching and construction of knowledge, and participation in in-service workshops emphasizing a constructivist approach to science (Pomeroy, 1993).

By detailing each aspect of the Nature of Science based on the Nature of Science Conceptual Scheme (from section Elements of the Nature of Science page 31), teachers' conceptions of the Nature of Science can be described.

1.1.1 Definitions of science

Abell and Smith (1994) found that teacher views of the definition of science could be categorized into six major groups based on analytic induction techniques; discovery, knowledge, process of science, explanation, and education. They found that most of the pre-service elementary teachers tended to focus on the knowledge and discovery aspects of the Nature of Science. Combined views on the definition of science were found in 40% of 140 student teachers. Most of these views were combinations of discovery and process, discovery and knowledge, and discovery and explanation.

Gess-Newsome's (2002) findings were similar. Before attending an elementary science methods course that emphasized the explicit instruction of the Nature of Science and Science Inquiry, most of the pre-service elementary teachers had unclear views of the definition of science and tended to define science as a

product and science as topics to be learned. After the course, most of them had clearer view and tended to have more blended view of the definition of science, science as a body of knowledge produced through the application of processes, and the process view of the definition of science, where science was seen as a process of gaining knowledge or applying process skills.

From the findings of Abell and Smith (1994) and Gess-Newsome (2002), it should be noted that teachers could have the combined views on the definition of science; discovery and process, discovery and knowledge, and discovery and explanation. They could also have blended views on the definition of science which view science as a body of knowledge produced through the application of processes. These views are acceptable views of the Nature of Science (Rubba and Harkness, 1993; Gess-Newsome, 2002). Moreover, it is possible to find that teachers defined science as the subject to teach which was categorized as an education view of science. This is because they viewed science from the teaching and learning context. However, it should be considered that teachers may express this view because they may not be able to distinguish science education (school science) from real science (scientists' science) (Abell and Smith, 1994).

In considering the interdependence of science and other disciplines, teachers see a close relationship between science and mathematics, technology, geography, and history, but little relationship between science and language, religious studies, art and music (Lakin and Wellington, 1994). The researchers suggested that teachers view science close to those disciplines because of the similar skills, approaches, content and philosophy underpinning those disciplines. Teachers also view science as distinct from the other disciplines because they do not view science as involving emotion, subjective observation, and imaginative thought, as suggested in those disciplines. However, some teachers have inadequate views, as they can not see science as a unique discipline involving a specific kind of knowledge about the world. They view science as vast and impressive (Abell and Smith, 1994). Additionally, they do not recognize the importance of empirical evidence or observation in distinguishing science from other disciplines (Akerson *et al.*, 2000).

1.1.2 Scientific knowledge

Research found that most teachers tended to see the source of scientific knowledge from the traditional view of science. They thought that scientific knowledge came totally from objective observation and had an empirical and experimental foundation (Pomeroy, 1993; Tobin and McRobbie, 1997). They saw that scientific claims or scientific knowledge represented truth, existed independent of the knower, and developed directly from observation (Tobin and McRobbie, 1997; Gess-Newsome, 2002). By this view, the scientific method, or observation, is the tool for generating and continuously verifying, proving or testing the truth in science or in scientific knowledge claims (Eick, 2000; Gess-Newsome, 2002).

Most of the teachers seemed to recognize that the validity of scientific knowledge, or scientific claims, was based on referring to observations of phenomena. However, while some teachers believed that observations could be made objectively and value-free, other teachers did not agree with this view (Murcia and Schibeci, 1999). Generally, the view that emphasized objective and value-free observation is classified as a traditional view of science (Pomeroy, 1993).

It was found that most teachers have only simplistic views of the nature of scientific knowledge. They had difficulty in formulating and expressing the differences between facts, laws, and theories in science (Eick, 2000). They did not realize that theory and law were different kinds of scientific knowledge serving different functions (Akerson *et al.*, 2000). Most teachers had a hierarchical view of facts, laws and theories in science. Their view was that theories become laws when they are proven, or viewed those hypotheses, theories, and laws as being developmentally related and having a developmental sequence (Rubba and Harkness, 1993; Akerson *et al.*, 2000; Eick, 2000). Most of them also failed to realize the role, function, and characteristics of theory and law in science. They tended to view theories as being similar to someone's ideas, scientific beliefs, or hypotheses, without being concerned with the foundation of empirical evidence. They rarely recognized that theory has a role as a framework to organize scientific knowledge, explanation, and to guide the research. They also saw scientific laws as facts which are absolute

and not subject to change (Akerson *et al.*, 2000; Eick, 2000; Akerson and Abd-El-Khalick, 2003).

Teachers seemed to have inadequate views of some specific characteristics of the nature of scientific knowledge. They were relatively unaware of the tentative nature of scientific knowledge (Murcia and Schibeci, 1999). Some teachers did not see scientific knowledge as tentative, but as able to be proven or disproven through the scientific method (Eick, 2000). They also believed that some theories will finally be proven and changed into laws. However, some of them thought that theories were changed through refinement or expansion rather than being rejected or replaced (Akerson *et al.*, 2000). Although they believed that scientific knowledge, such as theory, was uncertain and changed over time, they were not concerned about reinterpreting existing data or the role of new ideas to stimulate theory change. They tended to recognize only how advances in technology enhanced new discovery (Tobin and McRobbie, 1997; Akerson *et al.*, 2000). It was also found that most teachers lacked concern for the role of inference, human inference, imagination, and creativity in generating scientific claims, or constructing scientific models and theories (Akerson *et al.*, 2000).

1.1.3 Development of scientific knowledge

Research on teacher worldview presuppositions had found that science teachers from different non-western cultures had identical viewpoints. They seemed to agree more with metaphysical, parapsychological, pseudoscientific and scientific views than magic, mystical and spiritual views. However, their disagreement with rationalism and scientific views was generally higher than their agreement. This may reflect their inaccurate conceptions of the Nature of Science. The researchers concluded that teachers were influenced by both scientific and non-scientific worldviews. Additionally, science teachers from non-western cultures did not seem to make a clear demarcation between the scientific and non-scientific worldviews (Ogunniyi *et al.*, 1995).

In general, teachers seemed to have naïve views of the process of doing science and limited understandings of the scientific method. Most of them could give only a simplistic description of possible methods of data collection and emphasized observation, explanation, and experimentation as a crucial part of the scientific process (Rubba and Harkness, 1993; Murcia and Schibeci, 1999; Eick, 2000). They could rarely identify the procedures for controlled experiment and could not distinguish the difference between observation and inference. In addition, they did not have a detailed conception of the role of critical questioning in scientific endeavors (Murcia and Schibeci, 1999; Akerson *et al.*, 2000).

For the nature of scientific inquiry, research has found that a large number of teachers believed that scientists used only a single scientific method, or other sets of orderly and logical steps, as tools for their research (Akerson *et al.*, 2000). Some teachers had non-traditional views and saw that scientists could integrate many processes in their work (Pomeroy, 1993). Many teachers had simple views and a limited understanding of scientific inquiry. They viewed scientific inquiry as the posing of questions and investigation in order to learn the truths of science (Eick, 2000). They did not have clear understandings of the role of the scientist in creating explanations about the world (Abell and Smith, 1994). They tended to see science as individual work, rather than social or collaborative work and as an objective endeavour with scientists detached from their work. In addition, they attempted to eliminate the human perspective (Pomeroy, 1993; Murcia and Schibeci, 1999; Akerson, *et al.*, 2000). It was also found that teachers lacked an appreciation of the role of theories and disciplinary commitments in influencing scientists' activities and their interpretation of data (Akerson *et al.*, 2000).

For the role of imagination and creativity in science, most teachers thought that scientists could use creativity in the design stages of investigations and problem-solving, but did not think that they could use them for the development of scientific theories, models and explanations. They tended to restrict the interpretation of data and the invention of explanatory systems for explaining data with objectivity (Murcia and Schibeci, 1999; Akerson, *et al.*, 2000). Most teachers seemed to lack an awareness of the roles of imaginative thought, intuition, chance, 'one-off' ideas,

unrelated scientific and non-scientific sources, and abstract processes in the scientific method (Pomeroy, 1993; Lakin and Wellington, 1994).

1.1.4 Characteristics of scientists and scientific attitudes

Many teachers viewed scientists as unfamiliar extraordinary beings. They thought that scientists were not necessarily trained through the formal educational system. Important characteristics of scientists were their commitment and patience in their work, they were open-minded and open-hearted, and they showed due consideration to dissenting views. However, some teachers believed that scientists did not seem to permit possible disagreement in science (Rampal, 1992).

1.1.5 Interrelation between science, technology, and society

Teachers had more adequate views of the interrelation between science, technology, and society. However, although they recognized the existence of these relationships, they could not clearly explain them (Rubba and Harkness, 1993).

For the relationship between science and technology, it was found that most teachers did not distinguish between science and technology. They also had naïve views. They described technology as the application of science to enhance life and viewed science as a tool to solve problems in our world and help us in our daily lives (Rubba and Harkness, 1993; Eick, 2000).

For the relationship between science and society, most teachers seemed to have more understanding of social aspects of science. They accepted the possibility of scientists' background, personal beliefs and values, and research funding affecting their selection, interpretation, recording, or reporting of evidence (Murcia and Schibeci, 1999). On the other hand, many researchers found that some teachers failed to realize these social aspects of science. Some of them even stated that science was outside of the social world, devoid of the human element, and had negative relationships to culture, emotion and subjective observations (Rubba and Haskness, 1993; Abell and Smith, 1994; Lakin and Wellington, 1994). Teachers also

seemed not to realize the role of the scientific community in communicating or debating about competing theories (Abell and Smith, 1994). Additionally, they viewed scientists' work as value and ethics free (Murcia and Schibeci, 1999).

In the Thai context, the study about teachers' conceptions of the Nature of Science still lacks empirical evidence and deep information. There is also a range of different findings among the researchers (Bunmuangsan, 1997; Pholthum, 1997; Yotsapon, 1997; Khantha, 1998; Suksringarm and Suksringarm, 1998; Kingsoda, 1999; Phomburom, 1999; Taiyarat, 1999; Meesarphan, 2000; Guanamol, 2000; Srivinate, 2000).

Thai researchers surveyed school teachers' understanding of the Nature of Science by using similar standardized assessment instruments. They found that, in general, teachers seem to have adequate understanding of the Nature of Science as confirmed by the statistical evidence. However, when focusing on each specific aspect of the Nature of Science, they found that teachers had an inadequate understanding of some aspects, especially the characteristics of scientific knowledge. Teachers did not have adequate understanding of the amoral, creative, developmental, parsimonious and unified characteristics of scientific knowledge. They lacked the understanding that scientific knowledge:

provides humans with many capabilities but does not instruct us on how to use them; [is a product of the human intellect which required creative imagination; is] never proven in an absolute and final sense; ... tends towards simplicity, but not to disdain complexity; [and] produced by the various specialized science contributes to a network of laws, theories, and concepts [which gives explanatory and predictive power] (Lederman *et al.*, 1998: 339).

The possible inhibiting factors for their lack of understanding of the nature of scientific knowledge may be because of the lack of learning this aspect explicitly in the science content courses and training programs. Teachers might be left to construct their own understanding of these aspects by themselves through their general experience, their teaching and classroom observation (Pholthum, 1997).

In the other hand, some researchers found that teachers had more appropriate understandings of the nature of scientific method and the relationship between science, technology and society. The possible factors which enhanced teachers' understanding of the nature of scientific method might come from the enhancement of teacher training programs which emphasized teaching approaches of scientific inquiry and self-acquiring scientific knowledge. Thai teachers might also receive information about the interrelationship between science, technology and society from various media. Thus, their understandings of the Nature of Science in this aspect had been promoted (Pholthum, 1997).

1.2 Teachers' instruction of the Nature of Science

The instruction of the Nature of Science can be categorized into three major groups according to Akerson and Abd-El-Khalick's coding scheme (2003: 1032). Level 1 NOS (Nature of Science) instruction refers to "missed opportunities" to teach some aspects of the Nature of Science. This level does not refer to teachers not teaching the Nature of Science explicitly but rather to teachers not perceiving "the moment or activities at hand as a probable context for teaching something" or some aspects of the Nature of Science. Level 2 NOS instruction refers to implicitly addressing some aspects of the Nature of Science in the teaching. It includes some instructional activities with "isolated statements" which are consistent with some aspect of the Nature of Science, such as inquiry activities, but students do not have opportunities to consider or reflect explicitly on those aspects of the Nature of Science. Level 3 NOS instruction refers to explicitly addressing some aspects of the Nature of Science in the instruction. Teachers use some activities which explicitly engage students in constructing their understanding of some aspects of the Nature of Science, such as explicitly teaching about the distinction between observation and inference.

Based on this scheme, various researchers found that teachers generally teach the Nature of Science only at Level 1 and 2. Tobin and McRobbie (1997: 366-367) studied one high school chemistry teacher teaching the Nature of Science. They found that although this teacher had adequate conceptions of the Nature of Science,

these conceptions were “invisible in the enacted curriculum”. They observed that this teacher emphasized teaching facts about science and “memory joggers to the experiences of the demonstrations or the laboratory activities”. Lederman (1999) studied with five high school biology teachers teaching. He found that two experienced teachers taught science consistent with their appropriate views of the Nature of Science. They used many inquiry-oriented activities such as demonstrations and laboratories and students participated in collecting data, inferring explanations, and testing and revising the inferences. However, he found that these two teachers did not purposely emphasize concepts of the Nature of Science as their goals of instruction and students’ learning outcomes. He also found, similarly to Tobin and McRobbie, that one experienced teacher did not teach science in a manner consistent with her view of science. This is because she emphasized giving her students basic foundational knowledge of biology and she felt the concepts of the Nature of Science were too abstract for her students to learn effectively.

For the beginning teachers, Lederman found that even when teachers were interested in addressing the Nature of Science in their teaching, the Nature of Science was not obvious in their classroom practices because of the classroom management factor. For intern student teachers, Eick (2000: 6) found that while most of the interns viewed scientific inquiry in science as “the posing of questions and investigation of them in order to learn the truths of science”, they were using teaching strategies of inquiry, hands-on and laboratory practices to help students learn scientific concepts. Some frequently-used forms of inquiry activities were inquiry demonstrations, data gathering and exploratory laboratories, student-generated discussion and questioning on a topic of study, student-centered research projects, and hands-on activities that developed student understanding of concepts of study.

In a case of an elementary teacher, Akerson and Abd-El-Khalick (2003: 1035) had similar findings. In the early years of their professional development program, their participant, a fourth-grade teacher, taught science as in the Levels 1 and 2 NOS instruction, even though she had informed views and proposed to teach some aspects of the Nature of Science. They found that this teacher believed that “she was teaching about the Nature of Science by providing students with opportunities to

do science: that is, engaging them in activities and processes similar to those engage by scientists”. The general activities which this elementary teacher used in teaching science were using non-fiction children’s trade books for reading curriculum; setting student reading with science content and science time doing investigations and explorations; engaging students in handling equipment, making and recording observations, raising and attempting to answer questions, and engaging in discussions; having several field trips to engage in inquiry such as testing the water quality of a nearby river.

For Thai teachers, there is no research found studying teachers’ instruction of the Nature of Science. There is also a lack of deep information on Thai teachers’ understanding and teaching of the Nature of Science in order to help in enhancing the Nature of Science instruction. This is because all of the previous research found in Thailand is only survey research which emphasized eliciting the general or average information of teachers’ understanding or conceptions by using paper-pencil standardized assessment instruments. Research focusing on studying teachers’ teaching of the Nature of Science in classroom context can not be found. The study of factors influencing teachers’ understanding of the Nature of Science is based on only the quantitative analysis with statistical accounts. Even for teachers who seemed to have adequate conceptions of the Nature of Science, as elicited by quantitative research, a realistic picture of teachers’ understanding and teaching of the Nature of Science in the Thai classroom context is still vague.

1.3 Findings from the pilot study

In order to elicit Thai teachers’ understanding and teaching of the Nature of Science, this research has tried to develop and apply qualitative instruments to gain more deep information. The semi-structured interview with questions applied from some open-ended Nature of Science questionnaires (Abd-El-Khalick, 2001; Lederman *et al.*, 2002) had been trialled with three experienced lower elementary (Grades 1-3) teachers of Science.

This trial has found that all of three teachers viewed science from a teacher perspective and defined science within the group of educational views according to the categories of Abell and Smith (1994). From their view, science is the subject which needs practical work for teaching students to have scientific skills and analytical thinking. Science is also the subject which is different from other subjects because it has a number of processes and needs concrete examples. Two general teachers seemed to have no ideas about definition and differentiation among various kinds of scientific knowledge while one teacher who felt satisfied with teaching science had more ideas about this. However, this teacher's ideas seemed to fit with the traditional view of science and had some naïve views of the nature of scientific knowledge. This teacher viewed scientific knowledge as tangible, coming from experiments, unchangeable, proper and right which students should remember and use in their life. All of the teachers had devoted their ideas on the sources of scientific knowledge as scientific knowledge coming mainly from the practical process of observation, researching information from books, and doing experiments. They also viewed curiosity and thoughtfulness as the main characteristics of scientists.

While one teacher seemed to have less idea about the relationship between science, technology, and society, the other two teachers seemed to have more ideas. These two teachers viewed technology as having science or scientific knowledge as its foundation. This scientific knowledge was applied to advance technology. However, neither one mentioned the effect of technology on science. They both seemed to have simple views on the relationship between science and society. One of them thought that science had been used for social benefits such as repairing of antiques and ancient remains. Another teacher thought that the social aspect of science could be seen from the personal discipline in scientific practice, such as an individual should have personal discipline when doing scientific exploration.

This trial interview also asked teachers about teaching approaches or activities which they thought related to or reflected on the nature of the subject. According to their ideas, the appropriate approaches or activities are the use of news topics from the media to discuss and encourage students to recognize the values of science, some scientist's characteristics, or the relationship between science and

technology; practical activities of science process such as observation, experimentation, doing document or interview research and exploration of things surrounding them; questioning and discussion for practicing analytical thinking; field trips, such as going to a science museum, for students to see real things; and group work for students to practice the discussion and to work with each other.

These approaches and activities suggested by teachers seem to conform with the general approaches suggested by science educators for enhancing students' understanding of the Nature of Science. They also seemed to relate to their understanding of the Nature of Science obtained from the interview. However, the missing point of this interview is the lack of probing questions to elicit why teachers thought each of those approaches and activities relate to or reflect on the Nature of Science and how teachers use them to promote the conceptions of the Nature of Science.

This trial interview additionally asked teachers about their opinions on the factors affecting their teaching of Science according to the nature of subject. The six major factors identified by these three teachers are student, teacher, parent, school, time and subjects. They thought that student lack of writing and reading ability, maturity and interest; teacher lack of skills and interest in teaching science, lack of time to prepare equipment because of teaching many subjects; and school lack of science equipment and media and budget to buy equipment were the inhibiting factors to their teaching science. However, parents could be the enabling factor for their teaching by helping in preparing learning media and material, teaching their children and supporting student activities at home. Moreover, the school could help teachers by providing the funding for teachers to attend training programs. Finally, teachers' own experiences could also be an enabling factor for their teaching.

In an attempt to collect more accurate data on teachers' conceptions of the Nature of Science, this research developed and trialled a questionnaire on teachers' understanding of the Nature of Science instruction. This questionnaire combined open-ended questions on teachers' instruction of science with the rating scale statements on the concepts of the Nature of Science. This was to discover whether

teacher had a traditional view or contemporary view in each aspect of the Nature of Science.

The trial with ten experienced lower elementary (Grades 1-3) teachers of Science found that eight teachers had a mixed view between traditional and contemporary view of science in all aspects of the Nature of Science, except in the aspect of the interrelationship between science, technology, and society, where teachers seemed to have a more contemporary view of the Nature of Science. Two teachers were found to have contemporary views of all aspects of the Nature of Science. Most of the trial teachers had a naïve view about the nature of scientific knowledge and confusion between definitions of science and technology. Additionally, the findings about the instruction of the Nature of Science elicited by the open-ended section seemed consistent with the findings of previous interviews. Their conceptions of the Nature of Science also seemed to correlate with their views of instruction of science. However, their understandings, both of the concepts and the instruction of the Nature of Science, seem to be broad and simple.

Generally, the understanding of the Nature of Science of Thai lower primary school teachers found from this research pilot study seemed consistent with the international research findings. Thus, it would be possible to apply the findings from international researches to the development of the professional development program for Thai elementary teachers.

2. Assumptions and guiding principles of teachers' knowledge and development on the Nature of Science instruction

One of the general assumptions underpinning research on development of teachers' understanding and teaching of the Nature of Science is that it affects their classroom practice (Lederman, 1992). However, it has been found from qualitative research that teachers' understanding of the Nature of Science and their classroom practice are not related simply as a direct cause-effect relationship. There are a number of factors influencing the incorporation of teachers' understanding into their classroom practice. Lederman (1999: 916) had concluded that "teachers' conceptions

of science do not necessarily influence classroom practice”. Also, many science educators have claimed that improving teachers’ conceptions or views of the Nature of Science is necessary but insufficient for promoting effective instruction of the Nature of Science in the classroom (Abd-El-Khalick and Lederman, 2000; Bencze *et al.*, 2003).

Based on the conceptualization of teacher knowledge, teachers are required to have subject matter content knowledge, pedagogical content knowledge, and curricular knowledge in order to teach any subject content effectively (Shulman, 1986). For effective teaching of the Nature of Science, the understanding of the Nature of Science should be perceived as a cognitive learning outcome. The various aspects of the Nature of Science emphasized in contemporary science curriculum (as concluded in the Nature of Science conceptual scheme) should become the content of the targeted topic of study. Teachers should have the Nature of Science content knowledge (Abd-El-Khalick and Lederman, 2000). This consideration is beyond the previous ideas which emphasized the understanding of the Nature of Science to be only an affective learning outcome, a synthetic structure of science subject matter, or teachers’ epistemology (Matthews, 1994; Abd-El-Khalick and Lederman, 2000).

Teachers are also required to have the Nature of Science pedagogical content knowledge (NOS PCK) (Abd-El-Khalick and Lederman, 2000; Akerson and Abd-El-Khalick, 2003; Hipkins, Barker and Bolstad, 2004). This means teachers should have knowledge which combines subject matter knowledge and pedagogical knowledge. In the case of the Nature of Science instruction, teachers should have adequate understandings or conceptions of various aspects of the Nature of Science as well as the knowledge of how to teach those aspects of the Nature of Science effectively. They should know how to use various instructional approaches, resources, and media to teach the topic of science content in a manner that helps students understand the target Nature of Science aspects. For example, a teacher who has NOS PCK should be able to:

...comfortabl[y] discourse about NOS, lead discussions regarding various aspects of NOS [Nature of Science], design science-based activities that

would help students to comprehend those aspects, and contextualize their teaching about NOS with some examples or ‘stories’ from history of science ... examples and/or simplified case histories from scientific practice to substantiate this claim [socially and culturally embedded scientific knowledge] and make it accessible and understandable to students (Abd-El-Khalick and Lederman, 2000: 693).

In addition, to help teachers successfully translate their understanding of the Nature of Science into classroom practice, the influential factors for the instruction should be taken into account. Some examples of the important factors found from various research are teachers’ beliefs and intentions, level of experience, perceptions of students and judgment about students’ developmental readiness, personal theories or views of learning; science content-specific knowledge and support, and science self-efficacy; emphases in curriculum; classroom materials and resources for the Nature of Science instructions; and the realities of classroom constraints (Abd-El-Khalick and Lederman, 2000; Akerson and Abd-El-Khalick, 2003; Bencze *et al.*, 2003; Hipkins *et al.*, 2004).

Schwartz and Lederman (2002) suggested that teacher’s knowledge included in NOS PCK will be teachers’ beliefs that they can teach and their students can learn the Nature of Science; and teachers’ intentions to teach the Nature of Science as the basic and important requirements for teachers to teach the Nature of Science. Teachers who view science as a subculture and science learning as a culture-making process seem to place more emphasis on the sociocultural aspects of the Nature of Science in their teaching (Hipkins *et al.*, 2004). Teachers’ beliefs that they can teach and their students can learn the Nature of Science are likely to be increased when they see their students’ achievement in learning about the Nature of Science (Schwartz and Lederman, 2002). However, the beliefs and intentions to teach the Nature of Science seem to be limited by the frustration with classroom management and lesson plan organization of beginning teachers, and by the expectation of curriculum and assessment emphasizing teaching science content as the basic foundational knowledge for higher education (Lederman, 1999).

Another important factor for the teaching of the Nature of Science is the relationship between science content-specific knowledge and the Nature of Science content knowledge. It was found that teachers used the science content-specific knowledge in supporting their explanations of their views of the Nature of Science and supporting their teaching of the Nature of Science (Taylor and Dana, 2003). The research found that teachers' lack of science content-specific knowledge made them miss opportunities to explicitly teach some aspects of the Nature of Science (Akerson and Abd-El-Khalick, 2003). Additionally, Akerson and Abd-El-Khalick (2003) suggested that teachers needed the NOS-related content knowledge which is more supportive for teaching of the Nature of Science than declarative content knowledge such as facts, technical jargon or images provided in science textbooks.

In order to develop teacher's knowledge, beliefs and intentions as well as classroom practice the theory underpinning many effective teacher development programs relies heavily on the constructivist paradigm. The constructivist paradigm is "a set of beliefs about knowledge that begin with the assumption that a reality exists but cannot be known as a set of truths because of the fallibility of human experience" (Tobin, Tippins and Gallard, 1994: 47). This idea has been applied to many aspects of education, including teacher education and development. One form of constructivist paradigm which has been used as the theoretical framework for teacher development broadly is social constructivism. From the social constructivist perspective, learning is considered as "a social process of making sense of experience in terms of extant knowledge (including beliefs and images)" (Tobin *et al.*, 1994: 47). This means a person attempts to understand the new experience which they have interacted with through their own existing knowledge, beliefs and images with the mediation of their social and cultural environment. Thus, the attempts of individual "to make sense of phenomena" and "the role of the social in the mediation of meaning" are taken into account in the learning process (Tobin *et al.*, 1994: 47).

From the social constructivist point of view, the teacher is viewed as a learner. The attempt for teacher development should consider what teachers already know; how this knowledge can be represented; and what experiences teachers should be

provided to enable them to build an understanding of teaching and learning. Teachers are also viewed as persons who:

...experience teaching and learning situations and give personal meaning to those experiences through reflection, at which time extant knowledge is connected to new understandings built from experience and social interaction with peers and teacher educators (Tobin *et al.*, 1994: 48).

The social constructivist perspective leads to the perspective which views teachers as “professionals who think critically about themselves as practitioners and about contexts within which they work” (Gilbert, 1993: 21). This is the grounded perspective for teacher development which viewed individuals “as playing an active and creative role in the construction of experience; in which all knowledge development takes place in, and is dependent on, a social context” (Gilbert, 1993: 21). From this perspective, the effective approaches to develop teachers should be the ways that can raise teachers’ reflection of practice and help them to make judgments on or adjustments to their value and practice. This perspective also suggests that collaboration could be an effective approach to fostering teachers’ change, by teachers questioning, problem-posing, discussion and working together in small collaborative groups and practical activities (Gilbert, 1993).

In summary, there are four assumptions and guiding principles of teachers’ knowledge and development of the Nature of Science instruction. Firstly, teachers’ conceptions of the Nature of Science are necessary but insufficient for promoting effective instruction of the Nature of Science in the classroom. Secondly, teachers need to have NOS PCK in order to enhance their instruction of the Nature of Science. Thirdly, there are a number of the influential factors for the instruction of the Nature of Science should be taken into account. Finally, the professional development activities based on constructivist and social constructivist view of learning seemed to enhance teachers’ development of their understanding and teaching of the Nature of Science.

3. Characteristics of effective programs

In order to develop the in-service teacher, it was found that an effective teacher development model based on the social constructivist perspective could be used for enhancing primary school teachers' NOS PCK and classroom practice (Akerson and Abd-El-Khalick, 2003). This model for teacher development, proposed by Bell and Gilbert (1994), has three components, professional, personal, and social development, which have to be developed interactively and interdependently.

The professional development can occur based on the support of personal and social development. Firstly, teachers should have a chance to value their teaching competence and clarify any problematic aspect of their teaching within a supportive atmosphere. This is to initiate their awareness and acceptance of their professional dissatisfaction or problem, and enhance their desire to seek new teaching suggestions and new theoretical perspectives for their teaching and to learn how to put new ideas into action. Then, teachers should be engaged in both cognitive and classroom practice development. The cognitive development can occur via the clarification of their existing concepts and beliefs about science education or the targeted topics of development; obtaining an input of new information; constructing new understanding; considering, weighing, evaluating, and accepting or rejecting the newly constructed understanding; using their newly accepted understanding in a variety of contexts. The classroom practice can be developed by teachers obtaining new suggestions for teaching activities; considering them, visualizing, and planning for their use in the classroom; adapting and using new activities; sharing their classroom experiences with others and obtaining feedback about the use of the activities; evaluating the new teaching activities; and receiving support from facilitators, teacher colleagues, and their students. Teacher's reflection on their classroom actions in terms of the relationship between their actions and new theoretical ideas and the taking account of students' thinking is the important characteristic of this teacher professional development (Bell and Gilbert, 1994: 491).

To sustain the development of the teacher, their personal development should be improved to be able to deal with the restraints when they change their behavior and

role in classrooms. Teachers could receive support from facilitators and teacher colleagues as well as their students to make them feel secure and be willing to continue to use the new approaches in their classrooms. Teachers should reach a feeling of empowerment “to be responsible for their own development” (Bell and Gilbert, 1994: 492). Additionally, teachers should appreciate the social communication and interaction as important for their teacher development process and seek to initiate this collaboration further than only responding to “a facilitator-initiated activity” (Bell and Gilbert, 1994: 495) in the discussion and sharing sessions within the teacher development program. Importantly, the facilitator must encourage teachers to adopt the role of teacher-as-researcher and teacher-as-learner.

Akerson and Abd-El-Khalick (2003) found that in their case study with a fourth grade primary school teacher, the personal and social development are the crucial parts for the development of participant teacher’s instruction of the Nature of Science in her classroom. The teacher needs personal encouragement through discourse and exchange of ideas with a trusted colleague (the lead researcher) to externalize her conceptions about the Nature of Science and teach it explicitly. The researcher also supported the teacher’s understanding of how to teach the Nature of Science by modeling the Nature of Science instruction within her classroom. This contextual professional support was found effective in enhancing her teaching of the same aspects of the Nature of Science as modeling lessons in another classroom context. In addition, the teacher required the content-specific support explicit for the Nature of Science instruction and the Nature of Science instructional materials and resources for enhancing sustainable development of her teaching practice.

Teachers’ cognitive development in the Nature of Science conceptions can be promoted effectively by the use of an explicit approach for teaching the Nature of Science in the teacher development program (Abd-El-Khalick and Lederman, 2000). This approach can provide teachers with conceptual tools for eliciting and clarifying their existing conceptions of the Nature of Science such as engaging in critical incident activity and the Nature of Science profile activity (Nott and Wellington, 1998a; 1998b). This explicit approach can enhance teachers’ construction or reconstruction of their understanding of the Nature of Science by their reflection on

the activities they had engaged in such as discussion about some aspects of the Nature of Science arising from reading assignments, science stories, or historical case studies, and participating in open-ended inquiry, investigation, or other practical work. Additionally, other learning approaches, strategies, and techniques based on constructivist learning theory including conceptual change model, context-based learning, collaborative learning or peer coaching, reflection and feedback are found to effectively promote the conceptions of the Nature of Science (Bentley and Fleury, 1998; McComas, 1998b; Meichtry, 1998; Abd-El-Khalick and Akerson, 2004).

Teachers' classroom practice in the Nature of Science instruction can be enhanced by the use of the facilitator's modeling of the lessons within a science content course, science methods course, or real school classrooms. A teachers' appreciation of the importance of the Nature of Science and NOS PCK can also be enhanced by the teacher considering and analyzing the science curriculum; planning the Nature of Science lessons for their use in the classroom; sharing their classroom experiences with others; obtaining feedback about the use of the activities; and evaluating the new teaching activities. The facilitator can provide Nature of Science instructional materials and resources for supporting teachers' instruction (Clough, 1998; Bell, Lederman and Abd-El-Khalick, 2000; Schwartz and Lederman, 2002).

Additionally, Abd-El-Khalick, Bell, and Lederman (1998: 432) have suggested that the effective teacher development program, specifically for the Nature of Science instruction should emphasize four main aspects. The first aspect is to develop teachers' "understanding of the rationale behind, and a comprehension of, the importance of emphasizing the NOS in their teaching that goes beyond the customary discourse". The second is to give teachers much more extensive experience in teaching and assessing the Nature of Science based on "practical understandings of how students learn and what it takes to modify instructional activities to reinforce the development of adequate understandings of the Nature of Science". This teaching experience should be planned opportunities for teachers to engage in addition the left to chance opportunities. The third aspect is to give teachers support in their field experience. The last aspect is to help teachers to pay attention to explicitly teaching the Nature of Science. Teachers should be encouraged to oppose the idea that "the

Nature of Science can be taught implicitly through student participation in science activities”.

In conclusion, a program for in-service teacher professional development on the Nature of Science conceptions and instructions should be constructed based on the grounded perspective of social constructivism. For guaranteeing the effectiveness of the program, a teacher development model and approaches to teacher development based on the social constructivist perspective should be applied. The program should also emphasize the explicit approaches for the Nature of Science instruction for serving as ‘conceptual tools’ for teachers’ eliciting and clarifying of their existing conceptions as well as construction or reconstruction of their conceptions of the Nature of Science. The modelling of new teaching approaches, curriculum analysis and lesson planning, as well as classroom practice with facilitator and teacher colleagues’ support and feedback can possibly enhance teachers’ NOS PCK and their classroom practice. The design of activities within a teacher professional development program for the Nature of Science instruction should be considered based on four specific aspects of developing teachers’ understanding of the Nature of Science instruction. These aspects are developing teachers’ understanding of rationale behind the teaching of the Nature of Science; giving teachers’ extensive experience in teaching and assessing the Nature of Science; giving teachers the support in the field experiences; and developing teachers’ intention to teach the Nature of Science explicitly.

Summary

The Nature of Science is one of the important issues in science education which needs to be emphasized at every educational level. It is believed that by understanding the Nature of Science, students will become scientifically literate people who have a public understanding of science and higher order thinking.

Although definitions of the Nature of Science have tentative characteristics and elements, most contemporary curriculum frameworks and educational research

have a consensus of characteristics that can be summarized and used as the conceptual scheme for teachers in their teaching of this area.

The Nature of Science in this research is defined as; *the values and assumptions inherent in science, scientific knowledge, and the development of scientific knowledge which represents the unique characteristics of science as describing and explaining what science is, how it works and how it is different from other disciplines, what the scientist has done in the society throughout history, and how science and the scientist interact with the society.*

In order to promote the teaching and learning of the Nature of Science, teachers are required to have contemporary views of science rather than traditional views or misconceptions. Teachers should understand the elements of the Nature of Science covering the five main aspects of the Nature of Science in the conceptual scheme: definition of science; characteristics of scientific knowledge; development of scientific knowledge; characteristics of scientists; and interrelations between science, technology, and society.

Teachers should also recognize the importance of the Nature of Science as cognitive instructional outcomes and should understand how to plan and teach it explicitly in their classrooms. At this point, generally agreed characteristics for the Nature of Science instruction which could be included in Clough's important points can be used as the framework for the instruction. For elementary teachers, these assumptions can be considered collaboratively with the recognition of the relevant characteristics of children's ways of thinking and appropriate activities for elementary students. This would help their teaching of science and about science more effectively.

Thus, in this research, the Nature of Science conceptual scheme and generally agreed characteristics for the Nature of Science instruction are used as the framework of the research instruments and intervention collaboratively with consideration of Thai Science Curriculum Framework (2003) and Science Teacher Standards (2003).

In order to answer the first and second research questions, the Nature of Science conceptual scheme and general agreed characteristics for the Nature of Science instruction are used as the framework for designing research instruments and for interpreting data. In order to answer the third research question, the Nature of Science conceptual scheme and general agreed characteristics for the Nature of Science instruction are used as the framework for the Nature of Science content and instruction which will be promoted to teachers in the professional development program.

The design of this professional development program will be considered based on this content framework, data gathered from the previous instruments, and Thai science standards documents as well as the effective teacher development model, approaches to teacher development based on the social constructivist perspective, and the explicit approach for the Nature of Science instruction based on four specific consideration points for developing teachers' understanding of instruction of the Nature of Science.

CHAPTER III

METHODOLOGY

The first two chapters have shown the significance and theoretical framework of this research study. The development of teacher understanding and teaching of the Nature of Science has been emphasized. The review shows that teachers should have understanding of the elements of the Nature of Science covering five main aspects in the Nature of Science Conceptual Scheme. They should also appreciate the importance of teaching the Nature of Science explicitly and understand how to teach it explicitly and appropriately in their classrooms. Thai primary school teachers' understanding of concepts and instructional approaches of the Nature of Science and the effectiveness of an in-service primary school teacher professional development program on the instruction of the Nature of Science are central in this research study.

In this third chapter, the research methodology will be presented in order to clarify the process of inquiry used in this research. Case study as a research method will be identified. The details of research techniques and instruments to be discussed are research participants, research phases and timeline, research instruments and data collection, analysis procedures, management of the findings, and ways to ensure trustworthiness.

Methodological Paradigm for Research: Interpretive Research

This research was conducted mainly based on an interpretive methodological paradigm. The term *paradigm* in this research means “the worldviews or belief systems that guide researchers” (Tashakkori and Teddlie, 1998: 3). Based on an interpretive paradigm, the conceptions of social reality rely on the philosophical basis of idealism. The social world is viewed as existing “but different people construe it in very different ways, and organizations are invented social reality” (Cohen, Manion and Morrison, 2000: 9). The social researchers have a role in “discovering how

different people interpret the world in which they live”. Researchers usually focus on “individuals acting singly or together”. The “interpretation of the subjective meanings which individuals place upon their action and discovering the subjective rules for such action” becomes the method to understand the social world. Theory, in this paradigm, means “sets of meanings which people use to make sense of their world and behaviour within it [and the research is] the search for meaningful relationships and the discovery of their consequences for action”. The methodology based on this paradigm is “the representation of reality for purposes of comparison and usually uses the analysis of language and meaning”. This paradigm also views society and organizations as being “conflicted and governed by the values of people with access to power. The organizations [depend] upon people and their goals” (Cohen *et al.*,: 9). To make a change in society or organizations is to find out what values are embodied in organizational action and whose they are, then change the people or change their values if it is possible.

In the terms of ontology, epistemology, axiology, generalizations, causal linkage, and role of theory in relation to research, conceptions which are related to the conduct of research grounded in an interpretive paradigm are shown in Table 3.1 below.

Table 3.1 Conceptions of Several Orientations based on an Interpretive Paradigm

Orientations	Conceptions based on interpretive paradigm
Ontology (Nature of reality)	• There are multiple, constructed realities (Constructivism)
Epistemology (Relationship of the knower and the known)	• The knower and the known are inseparable (Interpretivism)
Axiology (Role of values in inquiry)	• Inquiry is value-bound
Generalizations	• Time- and context-free generalizations are not possible
Causal linkages	• It is impossible to distinguish causes from effects.
Role of theory in relation to research	• <i>Inductive logic</i> : Emphasizes arguing from the particular to the general or emphasizes grounded theory

Resource: Adapted from Tashakkori and Teddlie (1998)

This research aims to study teachers' understanding and teaching of the Nature of Science. The researcher is guided by many conceptions of interpretive paradigm as indicated briefly above. The researcher believes that the subject matter of social science or social reality, such as people and their actions, is different from the subject matter of natural science, such as atoms, genes, etc. The social subject matter tends to be more subjective and have fewer universal laws governing patterns of social phenomena (Bryman, 2001). The researcher is concerned that the understanding and teaching of each teacher in each school context is unique and has insight and meaning of its own. Teachers always have their own points of view in making sense of or interpreting the world surrounding them. They also have their own reasons for their actions in each situation. Thus, the researcher must try to gain access to teachers' thinking and interpret their actions and their social world from that point of view (Bryman, 2001).

To conduct research based on an interpretive paradigm, the forms of inquiry or logic of research procedures to investigate social phenomena should be different from those used in the investigation of natural science. It is suggested that researchers should use a qualitative or interpretive research strategy if the research aims to understand and explain the meaning of those educational processes and experiences (Bryman, 2001; Merriam, 1998).

The goal of this research is to develop teacher's understanding of concepts and instruction of the Nature of Science. In order to do this, it was a concern that the researcher should first understand the teacher's understanding and teaching of the Nature of Science in its natural setting with the consideration of possible factors affecting the teacher's teaching. Then, the intervention in the form of an in-service teacher professional development program for instruction of the Nature of Science was introduced and its effects on teacher's understanding of concepts and instruction of the Nature of Science was studied. In order to study the effects of intervention on teacher, there was a concern that the teacher should be the one who makes sense of and makes decisions on the use of information provided in the intervention to change their understanding and teaching. The development of teacher understanding of

concepts and instruction of the Nature of Science is an ongoing process. It is impossible to separate this phenomenon, the developmental process of teacher understanding, from the context of its study. Thus, the qualitative or interpretive research strategy is suitable for this research.

1. General Characteristics of Interpretive Research

The qualitative or interpretive research strategy is “the general orientation to the conduct of social research” (Bryman, 2001: 507) based on the interpretive paradigm. The ontological conceptions, epistemological conceptions, and other conceptions based on this paradigm as shown in Table 3.2 are all applied to the practice of this kind of research strategy.

Although the words *qualitative research* and *interpretive research* can be used interchangeably (Merriam, 1998), the researcher found it is useful to use *interpretive research* for presenting the fundamental methodological paradigm underpinning this research. The characteristics of interpretive research can be summarized within several focused points as shown in the Table 3.2 below.

Table 3.2 Characteristics of Interpretive Research

Focus Points	Characteristics of Interpretive Research
Focus of research	Quality (nature, essence)
Philosophical roots	Phenomenology, symbolism, interactionism
Associated phrases	Fieldwork, ethnographic, naturalistic, grounded, constructivist
Goal of investigation	Understanding, description, discovery, meaning, hypothesis generation
Design characteristics	Flexible, evolving, emergent
Sample	Small, non-random, purposeful, theoretical
Data collection	Researcher as primary instrument, interviews, observations, documents
Mode of analysis	Inductive (by researcher)
Findings	Comprehensive, holistic, expansive, richly descriptive

Resource: Adapted from Merriam (1998: 9)

From the table, at least five essential characteristics of interpretive research summarized by Merriam (1998) have been identified: the goal of eliciting understanding and meaning; the researcher as primary instrument of data collection and analysis; the use of fieldwork; an inductive orientation to analysis; and findings that are richly descriptive.

1.1 The goal of eliciting understanding and meaning - Based on the basic viewpoint that “reality is constructed by individuals interacting with their social worlds”, researchers who conduct interpretive research attempt “to understand the phenomenon of interest from the participants’ perspectives” or to understand how individual makes sense of their world and experiences (Merriam, 1998: 6).

1.2 The researcher as primary instrument of data collection and analysis - The research design for collecting and analysing data is flexible and usually relies on the researcher’s aptitude. The researcher is the one who mediates data and is responsive to the context of the research. The researcher can flexibly “adapt their techniques to the circumstances” (Merriam, 1998: 7) and consider the total context and situations through their sensitivity.

1.3 The use of fieldwork - “The researcher must physically go to the people, setting, site, institution (the field) in order to observe behaviour in its natural setting” (Merriam, 1998: 7). The researcher should also be familiar with the phenomenon being studied in order to describe and interpret it.

1.4 An inductive orientation to analysis - The abstractions, concepts, hypotheses, or theories are built up through the conduct of research. The researcher tries to find the theories to explain their data. There are no hypotheses to be deduced from theory to guide the research. The research findings are “in the form of themes, categories, typologies, concepts, tentative hypotheses, even theory, which have been inductively derived from the data” (Merriam, 1998: 7-8).

1.5 Findings that are richly descriptive - Researchers present what they have learnt about a phenomenon in the form of words or pictures rather than numbers. They use participants' own words, direct citations or excerpts from various sources of data to support their findings and conclusions. They also describe the "context of the study, the players involved, and the activities of interest" (Merriam, 1998: 8) to ensure the trustworthiness of their research.

The researcher notes that all of these characteristics of interpretive research strategy are fundamental characteristics of this research. The goal of eliciting understanding and meaning; the researcher as primary instrument of data collection and analysis; the use of fieldwork; an inductive orientation to analysis; and findings that are richly descriptive can be found through out the chapters presenting results and discussions.

2. Ensuring Trustworthiness in Interpretive Research

An interpretive research study is usually subjected to many issues concerning the quality of research. Bryman (2001) has presented several criticisms of qualitative research which are discussed below.

Qualitative research is too subjective This criticism raises the issue that "qualitative findings rely too much on the researcher's often unsystematic views about what is significant and important, and also upon the close personal relationships that the researchers frequently strike up with the people studied" (Bryman, 2001: 282). It usually makes the research readers to ask questions about "why one area was the chosen area upon which attention was focused rather than another" (Bryman, 2001: 282).

Difficult to replicate It is argued that qualitative research is difficult to replicate because its nature is "unstructured and often reliant upon the qualitative researcher's ingenuity" (Bryman, 2001: 282). The researchers are the main instrument of data collection, so the findings are subject to the researcher's

characteristics and abilities. Thus, there is “hardly [a] standard procedure to be followed” (Bryman, 2001: 282).

Problems of generalization It is argued that the findings of qualitative research can hardly be representative of all cases or be generalized to other settings or populations.

Lack of transparency In a qualitative research study it “is sometimes difficult to establish ... what the researcher actually did and how he or she arrived at the study’s conclusions ... The process of qualitative data analysis is frequently unclear” (Bryman, 2001: 283). In order to deal with these issues, the qualitative research should be conducted and reported in several ways which are discussed below.

Increasing the generalization – This can be achieved by inferring the findings of qualitative research to theories or theoretical reasoning, not to a population. “It is the quality of the theoretical inferences that are made out of qualitative data that is crucial to the assessment of generalization” (Bryman, 2001:283).

Increasing transparency and replication can be achieved by exhibiting “more of descriptive tenor, outlining the different ways qualitative researchers have gone about research or suggesting alternative ways of conducting research or analysis based on [their own, or others’, experiences]” (Bryman, 2001:283). Researchers can also conduct the qualitative research using a more narrowed-down and more structured design in collecting and analysing data. They may start with the general research questions, and then specify the theory or concepts which are arrived at during and after the data collection. Theories or concepts must then be tested against the data. Moreover, researchers can use more structured procedures or methods of analysing qualitative data to increase the transparency of the research (Bryman, 2001).

Many researchers have accepted that the interpretive research should be judged and evaluated by criteria which are different from and alternative to reliability

and validity which have been used in quantitative research. One of the criteria for assessing a qualitative or interpretive study is trustworthiness (Bryman, 2001).

The idea of trustworthiness comes from the belief that there can be more than one possible account of social reality. Thus, the degree to which any research is accepted by other researchers depends on its feasibility or credibility (Bryman, 2001). Trustworthiness is composed of four criteria, credibility, transferability, dependability, and confirmability paralleling the criteria used in quantitative research.

2.1 Credibility parallels internal validity. It is about answering the question of how believable the findings are. The credibility of research findings can be established by a researcher ensuring that research is carried out using good practice. The findings are submitted to the people who are subjects of or participating in the study to confirm that the researchers have a correct understanding of them and their social phenomena. A researcher can use several techniques to gain the confirmation or validation of research findings such as respondent validation or member validation, and triangulation (Bryman, 2001).

Respondent validation or member validation is a process in which a researcher gives an account of their findings, such as a report of observation or interview and a draft of research reports, to research participants. This is so the researcher will receive feedback from people in the study as to whether “there is good correspondence between their findings and the perspectives and experiences of their research participants” (Bryman, 2001: 273).

Triangulation is “the use of more than one method or source of data in the study of a social phenomena so that the findings may be cross-checked” (Bryman, 2001: 509). For example, a researcher may use observations with interview questions to check their understanding of what they have seen. The basic idea of this approach is “more than one method would be employed in the development of measures, resulting in greater confidence in [the] findings” (Bryman, 2001: 274).

2.2 Transferability parallels external validity. It is to answer the question of whether the findings apply to other context. Interpretive research tends to have qualitative findings with “contextual uniqueness” (Bryman, 2001: 272) which lack ability to be generalized to other contexts. Thus, the use of thick description will provide a database for other people to make “judgements about the possible transferability of findings to other milieu” (Bryman, 2001: 273).

2.3 Dependability parallels reliability. It is to answer the question whether the findings are likely to apply at other times or whether a measure is stable. It is suggested that researcher should keep complete records of all phases of the research process, from problem formulation to data analysis decisions, in an accessible manner. This is so peer researchers would be able to audit them to judge whether procedures are proper, provide sufficient data for drawing conclusions, and have fine theoretical inferences (Bryman, 2001).

2.4 Confirmability parallels objectivity. It is to answer the question whether the researcher has allowed their values to intrude in an investigation to a high degree. Although it is impossible to have complete objectivity in the conduct of social research, a researcher should have not overly allowed “their personal values or theoretical inclinations” to rule over the research and its derived findings (Bryman, 2001: 274).

In the conduct of this research, all of these criticisms of the quality of interpretive research and its trustworthiness in the research have been addressed. They have influenced the design and conduct of data collection and analysis procedures of this research. These issues will be identified, with their practical applications to this research, in the research methods section.

3. General Approaches to Interpretive Data Collection and Analysis

Another issue which is identified in this section is the general approaches to interpretive data collection and analysis. The data analysis procedure of interpretive

research tends to have different characteristics from the procedure used in quantitative research. Data analysis of quantitative research usually occurs after all the data have been collected from the data collection phase. However, the data analysis of qualitative research has a repetitive interplay with the data collection phase. Data analysis is conducted simultaneously with data collection (Merriam, 1998).

Generally, the analysis of data in interpretive research starts simultaneously with the collection of data. Researchers can analyse data while they are in the process of its collection. The findings of this analysis will then shape the next steps of the data collection process. Thus, data collection and analysis in interpretive research is an ongoing process (Merriam, 1998). The data analysis procedure of interpretive research also determines the process of data collection. The strategies for data analysis can be viewed as the strategies or framework of data collection (Bryman, 2001). Thus, the process of data collection and data analysis in interpretive research can be considered together.

The analysis procedure of interpretive research is viewed as “the process of making sense out of the data ...[and] involves consolidation, reducing, and interpreting what people have said and what the researcher has seen and read” (Merriam, 1998; 178). It is a complex process involving movements back and forth “between concrete bits of data and abstract concepts, between inductive and deductive reasoning, between description and interpretation” (Merriam, 1998: 178). Basically, it relies on the inductive mode of analysis. This means that researchers derive themes, categories, typologies, concepts, tentative hypotheses, or theories from the empirical findings of their investigation to interpret social phenomena under study (Merriam, 1998).

Based on an interpretive paradigm, a researcher encounters the third level of interpretation of a social phenomenon (Bryman, 2001). First, researchers describe how actors or people under study interpret their world. Second, researchers have to interpret participant’s interpretations. Thus, there is a double interpretation at this stage. Finally, researchers have to place their interpretations of the findings into “a

social scientific frame” (Bryman, 2001: 15). A social scientific frame of a research is accomplished by relating research findings to the existing concepts, theories, and literature of a discipline of a research field. This is the third level of interpretation.

In general, there is no concrete set of rules about how to collect and analyze qualitative data. However, there can be the broad guidelines provided (Bryman, 2001). Several general approaches to data analysis have been suggested (Merriam, 1998). Two analysis approaches related to this research study are discussed in the following section.

Content analysis in qualitative data analysis is a technique for analyzing content of interviews, field notes and documents. It aims to search for themes and recurring patterns of meaning from the messages which are communicated by focusing on frequency and variety of messages. The process of content analysis is composed of “simultaneous[ly] coding raw data and the construction of categories that capture relevant characteristics of the document’s content” (Merriam, 1998: 160). Content analysis is used to analyze interview transcripts for the presence or absence of the significant topics and to organize the discussion thematically after these significant topics (Oakley, 1999). However, this technique of analysis originally comes from quantitative research. It is “an approach to the analysis of documents and texts that seeks to quantify content in terms of predetermined categories and in a systematic and replicable manner” (Bryman, 2001:177). The use of this approach in this sense aims to analyze documents rather than generate meaning from data. Researchers must have specific research questions to guide the selection of documents and coding schemes set up. The crucial part of this analysis procedure is the designing of a coding schedule and a coding manual. The coding schedule is a form presenting all possible dimensions or topics to which all related data will be coded and classified. The coding manual is a corresponding statement presenting sub-categories under each dimension. Each dimension in a coding schedule may be composed of more than one coding manual in the form of list of sub-categories. The coding manual is used to guide the coders “in deciding how to allocate any particular code to each dimension” (Bryman, 2001: 186). The content analysis has been critiqued for its disadvantages as

data are often broken into small, decontextualised, and meaningless fragments, then, researchers as the outsiders, reassembled them using their own predetermined theoretical framework. Thus, theoretical explanations which emerge from this data may be overwhelmed by the researchers' values (Kellehear, 1993).

The constant comparative method or grounded theory strategy of data analysis aims to develop grounded theory which refers to the theory that is "grounded in the data and emerges from them" (Merriam, 1998: 190). This grounded theory consists of categories, properties (subcategories), and hypotheses. This method has been derived from basic ideas of "a researcher's understanding of [a subject of study or phenomenon] parallels that [the subject]'s view of itself" (Kellehear, 1993: 38). Thus, the analysis method tends to take data as the stimulus for the analysis "to overcome etic (outsider's) problems of interpretation [in the use of content analysis] by staying close to the emic (insider's) view of the world" (Kellehear, 1993: 39). The researchers' interpretation of studied phenomena should reflect the inside meaning embedded within them. This method can also be referred as *thematic analysis*. This is because the analysis task tries to discover and discern themes from data and give those themes names "with minimal preconceived categories" (Kellehear, 1993: 41) derived from existing literature. The categories have been taken from the data or field notes themselves. The key processes of this method are theoretical sampling, coding, theoretical saturation, and constant comparison. These key processes are designed to guide the generation of concepts, categories, hypotheses, and theory which are products of data analysis in order to generate meaning out of those data (Bryman, 2001; Kellehear, 1993; Merriam, 1998). Researchers collect data from various sources and compare data with each other. Tentative categories are generated through these comparisons. Then, comparisons are made between tentative categories in levels of conceptualization until a theory can be formulated (Merriam, 1998). This method of data analysis has been used broadly in qualitative research. However, there are several constraints in the application of this method. For example, it is generally agreed that researchers already have existing conceptualizations about the social phenomena being studied. Their investigations are theory-laden or build upon previous knowledge. Thus, researchers should aware of this when generating grounded theory.

Second, there are needs to tightly define research questions and plan an investigation as well as set tight deadlines. Thus, researchers sometimes can not “carry out a genuine grounded theory analysis with its constant interplay of data collection and conceptualization” (Bryman, 2001: 396).

In general, the important steps of data analysis in interpretive research involve data coding and category construction. The data coding and category construction are conducted in order that theoretical ideas for explaining the phenomenon studied to answer research questions will emerge. Although, there is no one correct approach to coding data and constructing categories, several guidelines can be used to determine their efficacy.

Researchers should start by generating an index of terms (codes) which will help in interpreting and theorizing the relationships within the data from reading through the data source and identifying significant remarks. Then, the codes should be reviewed again in order to see their relationship with the data and between the codes. It is suggested that researchers should consider whether their codes relate to concepts and categories in the existing literature. The researcher can possibly use concepts and categories in existing literature in order to guide the generation of general theoretical ideas about their data in their category construction. Sometimes, researchers may borrow categories or classification schemes from existing literature or sources outside the study. However, they should be concerned that borrowed categories or classification schemes may not be relevant and exactly fitted to all data of the study. Researchers also tend to select data for fitting into borrowed categories rather than letting new categories emerge from data. This hinders the purpose of interpretive research. Concepts, categories, and hypotheses which are generated should be reconfirmed by data. It is suggested that effective categories should reflect the purpose of the research, be exhaustive to enable placement of all important and relevant data into it, be mutually exclusive to enable fitting of a particular unit of data into only one category, be sensitive by clearly showing the meaning of phenomenon by each category's name, and be conceptually congruent to enable placement of each

category or subcategory in an appropriate conceptual level (Merriam, 1998; Bryman, 2001).

This research has applied the approaches of interpretive data collection and analysis in conducting the research. The details of processes of data collection and analysis will be identified in relation to their application to this research in the section on research methods. For the interpretation of the findings, the researcher considered the third level of interpretation of a social phenomenon (Bryman, 2001). The findings of this research would describe how participant teachers understand the Nature of Science both in its concepts and instruction approaches. Then, the researcher would interpret participant teachers' understanding and place these interpretations of the findings into a social scientific frame of this research. There would be a discussion of the findings with relating research findings from the existing literature in the research field of the Nature of Science. The readers can find these interpretations and discussions in the results and discussion chapters of this research.

Research Method: Case Study

The researcher chose the qualitative case study as research method of this study. Case study can support the investigations by gaining insight into, discovery of and interpretation of each specific phenomenon. It suits the situation that the phenomenon's variables can not be separated from their contexts. For this study, the researcher considers that teacher's understanding and teaching are the variables that can not be studied separately from the teacher's contexts. The purposes of a case study, "to arrive at a comprehensive understanding of the groups under study and to develop general theoretical statements about regularities in social structure and process", are consistent with this research's purposes (Merriam, 1998: 29). Case study can also support the study "to understand processes of events, projects, and programs and to discover context characteristics that will shed light on an issues or object" (Merriam, 1998: 33). It is useful for studying educational innovations and evaluating programs. This is because a case study can help researchers to gain concrete information about situations, settings, and human behaviours while they are engaging

in actions and interactions in various contexts. So, the researcher believes that by using the case study the effects of this research intervention and the development process of a teacher's understanding of the Nature of Science will be better understood.

The case study in this research referred to "an object of interest in its own right and the researcher aims to provide an in-depth elucidation of it" (Bryman, 2001: 49). The single case study of this research is each of four lower primary school teachers in one public primary school in the first educational area of Nonthabury educational area, under the Office of the Basic Commission, in the central region of Thailand. These teachers are teaching science as one of the core subjects in the academic year 2004-2005. This research focuses on elucidating each teacher's understanding and teaching of the Nature of Science in their school context and the development process of each teacher's understanding of the Nature of Science while they are engaging in a setting of the professional development program on instruction of the Nature of Science.

This research has combined two types of case study; interpretive and evaluative. Using the first type, the researcher gathers as much information as possible for analyzing, interpreting, or theorizing the teacher's understanding and teaching of the Nature of Science. The researcher tries to explain how participants come to any understanding and behaviors rather than just to describe them. This is a major characteristic of an interpretive case study. Using the second type, the researcher has designed the professional development program as being suitable for participants in the study. Then, this program has been used and evaluated in natural, holistic, dynamical, and qualitative accounts for better understanding of the dynamics of a program. This is a characteristic of an evaluative case study (Merriam, 1998).

This research can sometimes be seen as a multiple case study. This is because the research collects and analyzes data from four teachers which could be determined as four cases. Then, for the purpose of constructing the professional development program which suits all teacher participants, cross-case analysis has been used. This is to generate general theoretical explanations among these four teachers about their

understanding and teaching of the Nature of Science. The study of several cases and use of a cross-case analysis for suggesting generalizations of the findings among the cases are the features of a multiple case study (Merriam, 1998).

Research Techniques and Instruments

1. Research Participants

The research participants of this study are chosen by purposive sampling strategy and convenience sampling strategy. This is because this study is designed based on a case study research design which does not seek to represent participants to wider population (Cohen *et al.*, 2000).

In the sampling process of this research, firstly, the researcher has set the focus of inquiry to be any general teacher who teaches science in primary school level. Then, the researcher negotiated with one primary school administrator for gaining access to the samples. This school has been chosen based on the openness of school administrator for researcher to enter the site. This school administrator has become a source of information to help the researcher in making decisions about who should be included in this research. The administrator had discussed lower primary school teachers' need to be open-minded to any research and development about context of science teaching in this school. Thus, the researcher selected participants from four lower primary school teachers who are general teachers and teach science as one of the core subjects. So, these participants have been chosen based on the specific purpose and convenience of the researcher.

2. Research Phases and Timeline

There are four major research questions in this research.

1. Do primary school teachers have understandings of the instruction of the Nature of Science?

1.1 How do primary school teachers understand concepts of the Nature of Science?

1.2 How do primary school teachers understand the Nature of Science instructional approaches?

2. Do primary school teachers teach the Nature of Science and what are the factors affecting their instruction of the Nature of Science?

3. How does an in-service primary school teacher professional development program on instruction of the Nature of Science affect primary school teachers' understanding and teaching of the Nature of Science?

4. What do primary school teachers think about the advantages and disadvantages of an in-service primary school teacher professional development program on the instruction of the Nature of Science?

According to these research questions, the process of data collection and analysis are designed by composing three major phases.

Phase 1: Probing teacher's understanding, teaching and other factors

This phase is designed for collecting and analyzing data in order to describe and generate theoretical explanations for answering the first and the second research questions. Each participant teacher has been investigated for their understanding and teaching of the Nature of Science and factors affecting their teaching in the first semester of academic year 2004.

Phase 2: Developing an in-service professional development program

This phase is an intermediate phase. The researcher used a cross-case analysis to generate general theoretical explanations of teacher's understanding, teaching, and other factors affecting their teaching for each case. Then, the findings have been considered in the construction of an in-service teacher professional development program for the Nature of Science instruction. This is for ensuring that the program would be suited to all participants. This program has also been constructed based on general frameworks derived from existing literature of the Nature of Science

instruction. This program was constructed from the second semester of the 2004 academic year to the first semester of the 2005 academic year.

Phase 3: Implementing program and findings of its effectiveness

This phase is designed to investigate the effectiveness of the program on teacher's understanding and teaching of the Nature of Science to answer the third and the fourth research questions. The program has been implemented with the same group of participants during the period of the second semester of the 2005 academic year. During and after the implementation of program, each participant has been investigated to identify the development process of their understanding and teaching of the Nature of Science in order to determine the effectiveness of program. Each participant's opinions on the advantages and disadvantages of the program were also investigated after finishing the implementation of program in the second semester of the 2005 academic year. The research phases and timeline are presented in Figure 3.1 below.

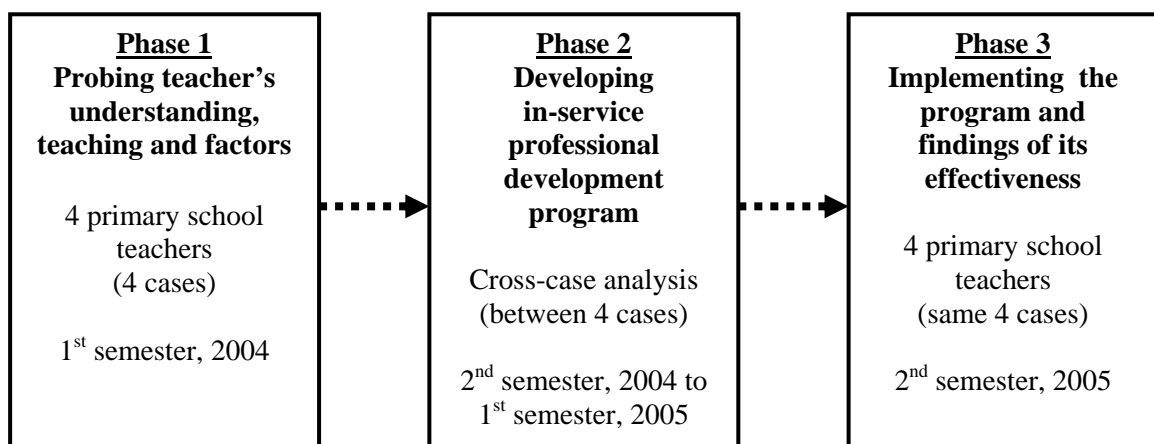


Figure 3.1 Research Phases and Timeline

3. Research Instruments and Data Collection

There are four major techniques and instruments of data collection used in this research.

- 3.1 Observations with field notes, informal interviews, and videotape recording
- 3.2 Document and content analysis
- 3.3 Semi-structured interviews with audiotape recording
- 3.4 The Nature of Science Instruction Questionnaire (NOSI questionnaire)

3.1 Observations with field notes, informal interviews, and videotape recording

The non-participant observation technique was used in this research (Verma, 1998). In the first phase and third phase of this research, classroom observation with field note taking was employed by the researcher to find out data of each participant's teaching of the Nature of Science in their real classroom setting. Regarding the reliability of the classroom observation with a focus on that teachers' teaching, the researcher started by introducing herself to the participant teachers.

In the first phase of the research, the researcher had spent some time visiting their school and had formal interviews with them before doing classroom observation. The researcher visited each participant's science class 1-2 periods. The researcher sat at the back of the classroom, as unobtrusively as possible, observed and took field notes to record the teacher's actions and teaching activities in the classroom. After the class, the researcher had an informal interview with the teacher. The interview aimed to obtain information about the teaching objectives, intentions, and perceptions of that classroom teaching. The sample of a field note is shown in Appendix F.

In the third phase of the research, classroom observation occurred after the researcher and participant teachers had spent twelve sessions of after school training program together. Thus, teachers were familiar with the researcher and accustomed to the researcher's presence in the classroom. The researcher visited each participant's science class 1-2 periods and used the same observation technique as in the first phase.

There was the observation of the program implementation in the third phase of the study. This observation was done by two co-researchers using non-participant observation with field note taking and videotape recording. The researcher took action as facilitator who implemented the training program with the participant teachers. One co-researcher had the role of using video tape recording the activities which occurred in each training session. Another co-researcher had the role of taking field notes. This observation aimed to obtain information about teachers' participation in and facilitator's implementation of the program. This observation helped the researcher to keep the training activities in line with the planning task and to reflect on her own actions after implementing each training session in order to improve and apply the activities session by session.

3.2 Document and content analysis

This research refers to this technique following Anderson (1994, cited in Verma, 1998: 112)'s definition of it as "the systematic description of the contents of documents". In order to find out participants' understanding of concepts and instructional approaches of the Nature of Science, various documents were gathered in the first and the last phase of the study. These documents were participants' lesson plans, teachers' notes, and written documents generated during participation in the program. Then, documents were identified and their contents classified based on the Nature of Science conceptual scheme and coding scheme for the Nature of Science instruction (*see* Appendix C and D). Finally, the findings were interpreted and triangulated with data from other sources.

3.3 Semi-structured interviews with audiotape recording

The semi-structured interview is in between two extreme types of the interview, the structured interview and the unstructured or open-ended interview. It has an interview schedule to ensure that the researcher can collect data relevant to objectives of the study, can make good use of time and resources, and can balance between "allowing the variety of responses from one interviewee to another and

reasonable consistency in the interviewer's approach" (Verma, 1998: 125). The interview schedule can be in the form of a statement of the topic in the next part followed by a general question. It is commonly composed of a series of opening statements, primary questions and supplementary questions (Verma, 1998). This type of interview allows the interviewees to respond flexibly to the questions, and allows the researcher to generate supplementary questions or probing questions to deeply explore issues of interest.

For the first phase of this research, the interview schedule was constructed based on the three following objectives.

- To discover information about basic education and teacher training, teaching experience, job loading, working contexts and interests of participant teacher. This information would be used as fundamental data for developing a primary school teacher professional development program on instruction of the Nature of Science.

- To discover the participant teacher's understanding of the instruction of the Nature of Science in the aspects of curriculum, concepts of the Nature of Science, instructional approaches for the Nature of Science, and general teaching approaches for Science.

- To discover the participant teacher's opinions on the factors which influence their instruction of the Nature of Science.

The interview schedule is composed of three main parts related to the objectives: basic information about the participant teacher; understanding of instruction of the Nature of Science; and opinion on the factors which influence instruction of the Nature of Science. Each part is composed of several primary questions and with some guided supplementary questions. For the second part of this schedule, in order to investigate teacher's conceptions of the Nature of Science in five major aspects according to the Nature of Science conceptual scheme, the researcher applied question items from open-ended questionnaire instruments included in a questionnaire developed by Abell and Smith (1994), and View of Nature of Science

questionnaire (VNOS) developed by Lederman *et al.* (2002). The interview question items from these sources were applied and translated into Thai. The interview schedule was reviewed and suggestions for improvement of the content validity were made by three Thai science educator experts. Then, the semi-structured interview was modified and was trialled with three lower primary school teachers who were in a similar context to the study before being used in this study. The sample of this interview schedule is presented in the Appendix B. In the first phase of this research, each participant teacher was interviewed with audiotape recording for approximately 45 minutes.

For the third phase of this research, the researcher modified the previous interview schedule to investigate participant teachers' understanding of instruction of the Nature of Science after attending the professional development program and to find out their perspectives on the advantages and disadvantages of the program. This modified interview schedule was composed of the following three objectives.

- To discover information about basic education and teacher training, teaching experience, job loading, working contexts and interests of participant teacher. This information would be used as supplementary data for assessing the effectiveness of the program.

- To discover the participant teacher's understandings of instruction of the Nature of Science in the aspects of concepts of the Nature of Science and instructional approaches for the Nature of Science.

- To discover the participant teacher's perspectives on the advantages and disadvantages of the program.

The modified interview schedule is composed of three main parts relating to the objectives: basic information about the participant teacher; their understanding of instruction of the Nature of Science; and their perspectives of the advantages and disadvantages of the program. Each part is composed of several primary questions and with some guided supplementary questions. After the program finished,

participant teachers were interviewed individually for approximately 45 minutes per person with audiotape recording.

3.4 The Nature of Science Instruction Questionnaire (NOSI questionnaire)

In this research the NOSI questionnaire was developed after the semi-structured interviewing as a sole instrument for gathering information about participant teachers' understanding of concepts and instruction of the Nature of Science. This was because the researcher considered that the semi-structured interview used previously had gained information complementary to the questionnaire (Verma, 1998). It was found that by using the semi-structured interview, some specific concepts of the Nature of Science according to the conceptual scheme held by participant teachers were not elicited. The researcher suspected that it was because the questions of the interview were too broad and lacked consideration of the teachers' contexts. Thus, the NOSI questionnaire was constructed to cover different but related and more specific aspects of the concepts of the Nature of Science. This questionnaire was also designed for gaining supplementary information about teachers' understanding of instructional approaches for the Nature of Science.

This questionnaire was developed firstly in English with suggestions and supervision of two experienced science educator researchers. Then, it was translated into Thai and was reviewed and suggestions were made to improve its face and content validity by two Thai science educator experts and three Thai research supervisors. The questionnaire was modified and was trialed by eleven teachers who were in similar contexts to the study before being used with participants.

The final form of the NOSI questionnaire contains three parts (*see* Appendix A). The first and second parts are composed of check lists and open-ended questions to find out participant teachers' general information and understanding of the teaching of science related to concepts and instruction of the Nature of Science. The last part consisted of 29 rating scale statements on the ideas of the Nature of

Science to find out participant teachers' understanding of specific aspects of the Nature of Science. These statements about the Nature of Science were applied from various assessment instruments (Aikenhead and Ryan, 1992; Cobern and Loving, 1998; Hammerich, 1998; Nott and Wellington, 1998; Haidar, 1999; Tairab, 2001).

The NOSI questionnaire was handed to each participant teacher for response within approximately 30 minutes in both the first and the last phases of the research. In the last phase of the research, a new questionnaire was handed to each participant to respond to before attending the professional development program. Then, after having finished the program and the individual interview, the same questionnaire which participants had answered was handed back to them. Each participant was asked to read and revise their answers on the NOSI questionnaire within approximately 20 minutes.

The procedure of data collection in each research phase can be summarized and presented separately as following.

Phase I: Probing Teachers' Understandings, Teaching and Other Factors

According to the research questions, there are three major variables to study.

- 1) Understanding of the Nature of Science in two aspects
 - 1.1) Concepts of the Nature of Science
 - 1.2) Instructional approaches for the Nature of Science
- 2) Teaching practice of the Nature of Science
- 3) Factors affecting the participants' instruction of the Nature of Science

The overall procedure of data collection and analysis can be summarized as Figure 3.2. The researcher has used multiple methods of data collection to gain information from various sources. Some techniques and instruments such as semi-structured interviews and the Nature of Science instruction (NOSI) questionnaire have been used to gaining specific information about teacher understanding of concepts and instruction of the Nature of Science. Classroom observation with field note taking and informal interviews, and documentary and content analysis have been used together for gathering data about teacher's understanding and teaching of the Nature

of Science and factors affecting their teaching from wide and holistic context of the study. The information generated from these various sources and techniques was also cross-checked during data collection and analysis process.

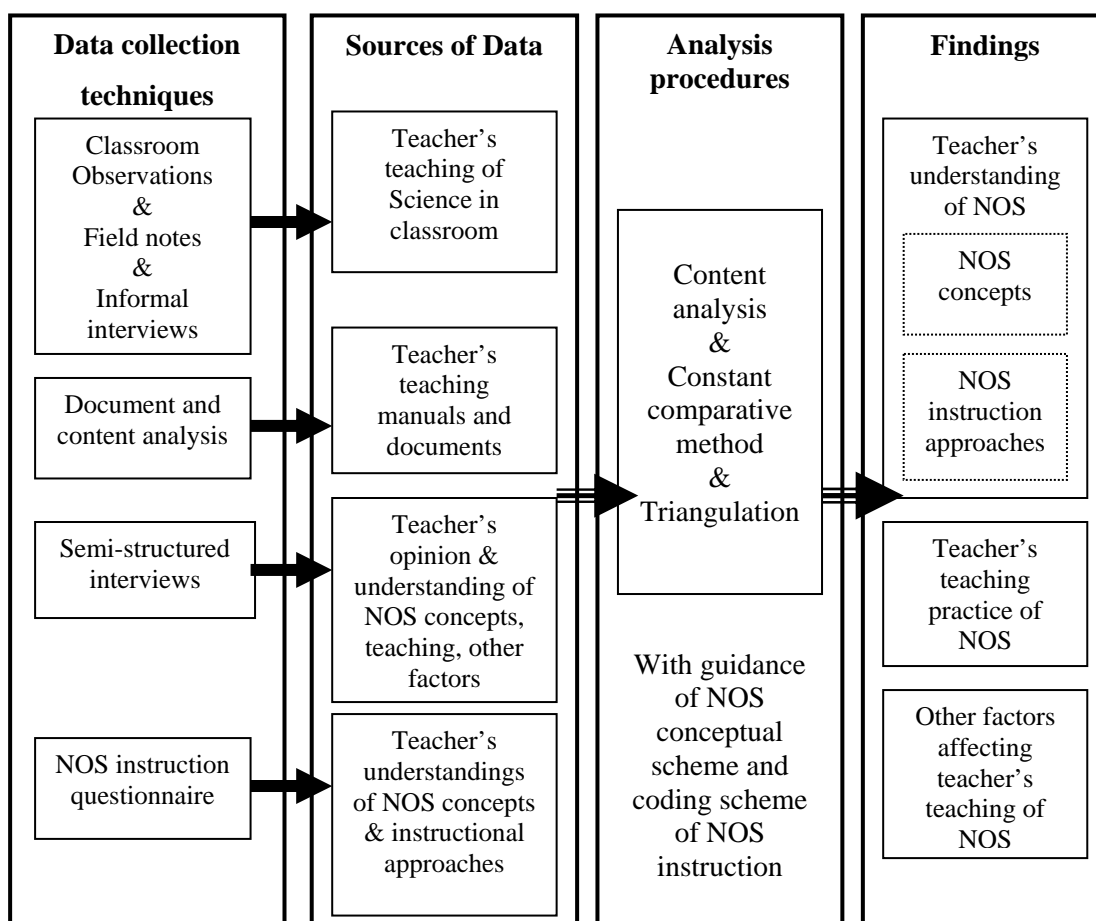


Figure 3.2 Data Collection and Analysis Procedure of Phase 1

Phase 2: Developing an in-service professional development program

This phase was the construction of an in-service teacher professional development program for the Nature of Science instruction. This program is constructed based on several considerations; the findings from the first phases, Thai science standards documents, the effective teacher development model, approaches to teacher development based on the social constructivist perspective, the explicit approach for the Nature of Science instruction, and content framework derived from the Nature of Science conceptual scheme and general agreed characteristics for instruction of the Nature of Science. Then, the program was audited and improved

based on suggestions of experts in science education in order to ensure its efficiency and practicality. The overall procedure of the construction of the program is summarized as Figure 3.3 below.

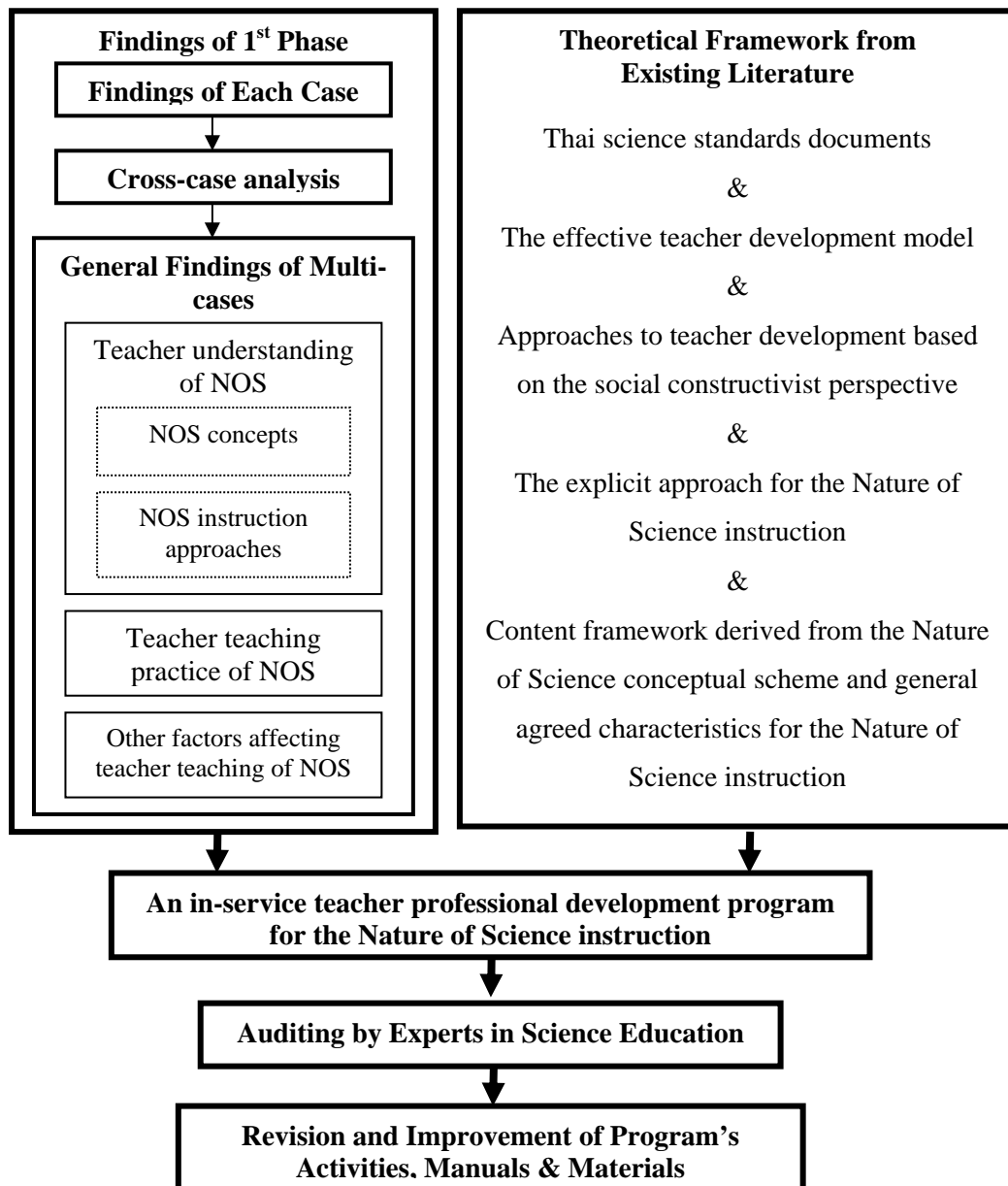


Figure 3.3 Construction Procedure of an In-service Teacher Professional Development Program for the Nature of Science Instruction

Phase 3: Implementing program and findings of its effectiveness

According to the research questions, there are three major variables to study.

1) Understanding of the Nature of Science during and after participating in a program in two aspects

1.1) Concepts of the Nature of Science

1.2) Instructional approaches for the Nature of Science

2) Teaching practice of the Nature of Science after participating in a program

3) Perspectives on the advantages and disadvantages of the program

The overall procedure of data collection and analysis is summarized as Figure 3.4 below.

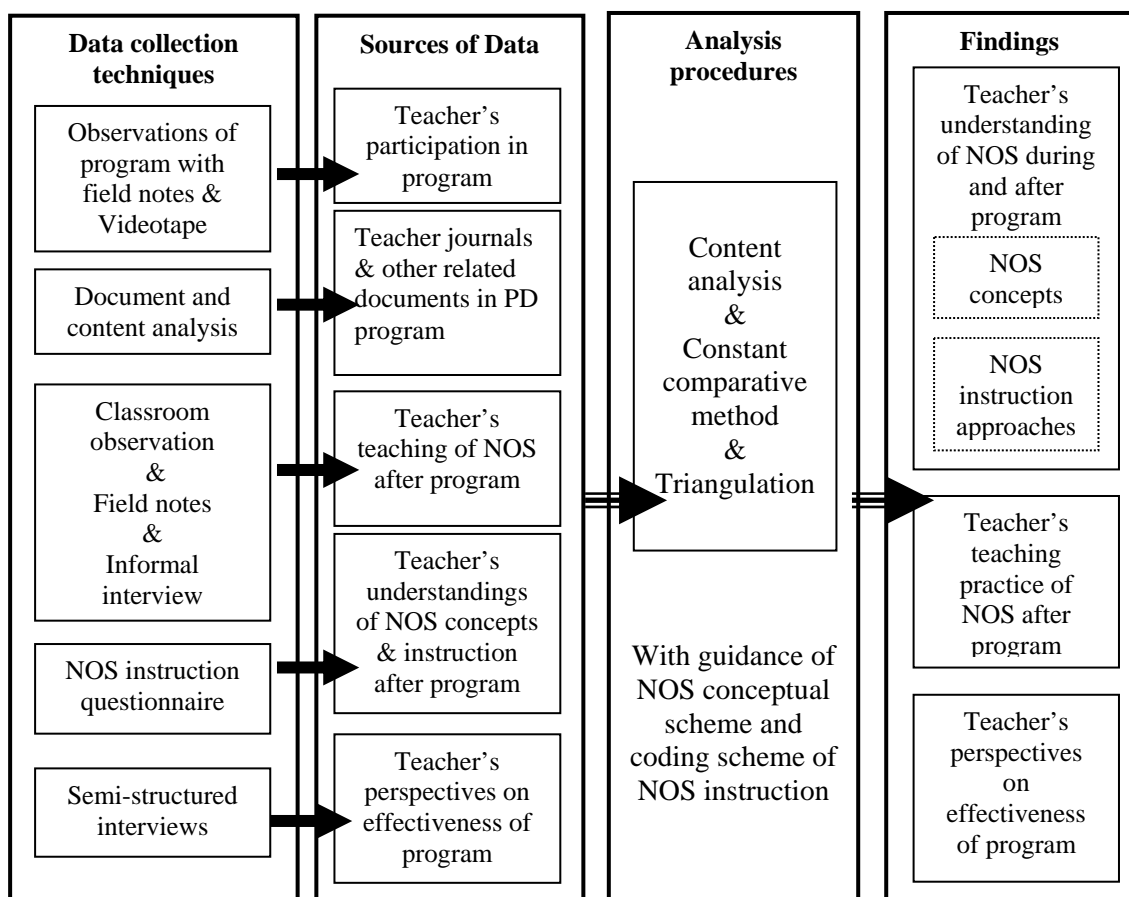


Figure 3.4 Data Collection and Analysis Procedure During and After Program Implementation

During program's implementation, the researcher used multiple techniques and instruments for gaining data about each teacher's understanding and teaching of

the Nature of Science during and after participation in the program. Two major techniques were observation of the program with videotape recording and field note taking by co-researchers. The researcher had to use videotape to help record participants' conversations and behaviours while engaging in the program activities because researcher had taken role as facilitator implementing the program. Thus, videotape recording and field note taking by co-researchers helped to capture the details of situations in this setting. These also helped the researcher when reviewing and reflecting on the implementation of each session. The researcher gathered related documents which participants generated during participation in the program such as teacher's notes and lesson plans. This was for eliciting participants' understanding of the Nature of Science from these sources based on content analysis.

After the program, participant's understanding of the Nature of Science was assessed again by the Nature of Science instruction questionnaire. The same questionnaires which participants had answered at the beginning of the program were distributed to each of them. Participants were asked to revise their previous answers. Participant's teaching of the Nature of Science was also observed with field note taking and informal interviews. Participant's perspectives on the effectiveness of the program also had been gathered by semi-structured interview. Then, the information generated from these various sources and techniques was analysed categorized and cross-checked.

4. Analysis Procedure

The researcher has used the Nature of Science conceptual scheme and the coding scheme of the Nature of Science instruction to guide the design of the coding list and analysis task in the content analysis process and constant comparative method.

In the first phase, semi-structured interview responses of each participant teacher were transcribed and categorized into four major groups; teacher's general information and background, understandings of concepts of the Nature of Science,

understanding of instruction of the Nature of Science, and factors affecting teaching of the Nature of Science. The understandings of concepts of the Nature of Science were also categorized into five major subgroups: definitions of science; scientific knowledge; development of scientific knowledge; interrelation between science, technology, and society; and characteristics of scientists and scientific attitudes. In the third phase, the responses of the semi-structured interview were transcribed and categorized into four same major groups with one more group added. This new group was the data of teachers' perspective on the program.

Each participant teacher's responses on the first and second part of the NOSI questionnaire were coded and categorized into the three major groups; teacher's general information and background, understanding of instruction of the Nature of Science, and understanding of concepts of the Nature of Science. The responses on the rating scale part of the NOSI questionnaire were scored and calculated for the mean score. Then, these responses were analyzed and categorized into the range from strongly traditional view to strongly contemporary view of science and into the range from do not have understanding to have correct conception of the Nature of Science. These responses on each question item were also categorized into five major subgroups of concepts of the Nature of Science based on the coding lists (*see* Appendix C, D and E).

Data from classroom observation and field notes and Data from documentary included teacher's lesson plans, teacher's notes, and written documents generated during participation in the program were coded and categorized based on the coding scheme of the Nature of Science instruction. These data were grouped into two major groups; understanding of instruction of the Nature of Science and teaching of the Nature of Science. Under the group of understanding of instruction of the Nature of Science, there were two subgroups; objective of science teaching and teaching approaches. Under the group of teaching of the Nature of Science, there were four subgroups; classroom setting, introductory, teaching and learning activities, and conclusion of the lesson.

Data from observation of program implementation with field note and videotape recorder were coded and categorized into two major groups; teacher's understandings of concepts of the Nature of Science during participated in the program and teacher's understanding of instruction of the Nature of Science during participated in the program.

To ensure the validity of interpretation, data from all resources were cross checked by putting data from each resource in the table under the same heading. The sample table of data cross checking is shown in Appendix G. In order to do cross case analysis, data from each participant were also putting into the table under the same heading. The sample table of cross case analysis is shown in Appendix H.

5. Management of the Findings

To help in eliciting the effectiveness of the training program created for this research, the findings of each case have been organized as each teacher's profile. Each profile of each case comprises:

- 1) Teacher background and participation in the training program;
- 2) Teacher understanding of the Nature of Science before, during, and after the program;
 - 2.1) Understanding of concepts of the Nature of Science;
 - a. Definitions of science;
 - b. Scientific knowledge;
 - c. Development of scientific knowledge;
 - d. Interrelation between science, technology, and society;
 - e. Characteristics of scientists and scientific attitudes;
 - 2.2) Understanding of instructional approaches for the Nature of Science;
- 3) Teacher's teaching of the Nature of Science before and after the program;
- 4) Factors affecting their teaching of the Nature of Science;
- 5) Teacher perspectives on the advantages and disadvantages of the program.

The effectiveness of the program was determined in the form of each teacher's development of their understanding of the Nature of Science and each teacher's perspectives on the advantages and disadvantages of the program. By using this profile, the researcher could track the progress of each teacher's understanding and teaching of the Nature of Science by comparing them before, during and after the program implementation. Then, the cross case analysis has been done for the generation of general theoretical explanations about the effectiveness of this program across the four cases.

Additionally, to help draw out the context and reality of a program implementation, the findings from the observation with field notes and the researcher's reflection on the program implementation have been analyzed and presented in the section on the program implementation process, context and factors which affect it in Chapter 4.

6. Trustworthiness of Data Generation and Analysis

To ensure the trustworthiness of this study, the researcher has tried to conduct the research in a manner which would enhance credibility, transferability and dependability, and confirmability as described below.

6.1 Credibility The researcher used multiple methods and sources of data and cross-checked between the findings to ensure the credibility of this research.

6.2 Transferability and Dependability To increase the generalizability of this research, researchers tried to report all the related details of methods of data gathering and analysis including with context of and reasons behind the study. In the sixth chapter, one section is devoted to describing the context of the implementation of an intervention. Based on the details of the data collection and analysis methods, researcher hopes that the readers will be able to assess the degree to which these methods are consistent with the findings. This research also used cross-case analysis

to generate the general theoretical explanations of the findings among four cases. This analysis helps to increase the generalizability of the findings.

6.3 Confirmability Although the researcher had an existing theoretical framework for analysis of data, the researcher was still open to the alternative findings which may have emerged from various sources. The theoretical framework, such as the Nature of Science conceptual scheme and the coding scheme for the Nature of Science instruction, are only a guideline for interpretation of the data. This framework could be changed as new alternative theoretical explanations emerged from the data. Thus, the researcher tried to control the influence of personal values and theoretical framework so they would not overwhelm the objectivity of findings generation.

Summary

The research methodology of this study is based on an interpretive methodological paradigm and a qualitative or interpretive research strategy has been employed. The research design or a framework for the collection and analysis of data is the qualitative case study. The researcher considered that the case study can help researchers to gain concrete information about situations, setting, and participants' behaviours while they are engaging in the program. The researcher believed that by using the case study the effectiveness of this research intervention and the development process of teacher's understandings of concepts and instructional approaches of the Nature of Science will be better understood. The single case of this research is each of four lower primary school teachers who taught science as one core subjects in the 2004-2005 academic years in one public primary school, in the first educational area of Nonthabury educational area, under the Office of the Basic Commission, in the central region of Thailand. These participants were chosen by a purposive and convenience sampling strategy.

The process of data collection and analysis were designed in three major phases from the first semester of the 2004 academic year to the end of the 2005 academic year. Phase 1 was to probe teacher's understanding, teaching and other

factors in the first semester of the 2004 academic year. Phase 2 was to develop an in-service professional development program during the second semester of the 2004 academic year and the first semester of the 2005 academic year. Phase 3 was implementing the program and discovering its effectiveness in the second semester of the 2005 academic year. Four research techniques and instruments were used for data collection: (a) observation with field notes, informal interviews, and videotape recording; (b) document and content analysis; (c) semi-structured interviews with audiotape recording; (d) and the Nature of Science Instruction Questionnaire (NOSI questionnaire). The content analysis and constant comparative method with the coding schedule and coding manuals derived from the Nature of Science conceptual scheme and coding scheme to the Nature of Science instruction are the analysis procedure of this research. The multiple methods and sources of data, cross-checked between the findings, were used to ensure credibility of the research. The findings of each case have been organized as each participant teacher's profile comprising teacher background; teacher understanding of concepts and instructional approaches of the Nature of Science before, during, and after participating in the program; teacher's teaching of the Nature of Science before and after the program; factors affecting their teaching of the Nature of Science; and teacher perspectives on the advantages and disadvantages of the program. The next chapter will present the program formulation and implementation.

CHAPTER IV

PROGRAM FORMULATION AND IMPLEMENTATION

An in-service primary school teacher professional development program on instruction of the Nature of Science was developed during the second semester of the 2004 academic year and the first semester of the 2005 academic year. It was the second phase of this research. The overall procedure of the construction of this program was summarized in the previous chapter, under section Data Collection and Analysis Procedures. Findings from the first phase of the research were used as a part of the guiding principles for the program construction. These findings will be presented in detail in the next chapter. For this chapter, the program details in aspects of the guiding principles of underpinning, program features, and program validation are presented. This chapter also presents the process, context, and factors affecting this program implementation.

Framework of the Program Construction

The framework of this program construction is from two major resources. The first resource is from the findings of phase 1 of this research. The second resource is from the theoretical framework from existing literature. The consideration of how these resources provided the guide line for the program formulation is illustrated as below.

1. Findings of Phase 1 across Five Cases in the 2004 Academic Year

Findings from the first phase of this research study brought important information from participant teachers. This information comprised participant teachers' background relating to their science instruction, their understanding of the concepts of the Nature of Science in the five major aspects, their understanding of the

instructional approaches for the Nature of Science, their teaching practices, and other factors affecting their teaching.

The findings of the first phase guided the researcher in setting the aims and contents of the program. The researcher considered that participant teachers should expand their understanding of the concepts of the Nature of Science to become more contemporary in their view. Their traditional view and inappropriate understanding of the concepts of the Nature of Science in all five major aspects should be challenged and modified. Participant teachers should be encouraged to recognize and appreciate the understanding of the Nature of Science as a cognitive learning system to be explicitly taught and assessed in science classes. They should be encouraged to understand how to explicitly address the concepts of the Nature of Science and observe explicitly modelled behavior that reflected an appropriate understanding of the concepts of the Nature of Science, science processes and process skills in their science teaching and learning activities.

2. Theoretical Framework from Existing Literature

There are five groups of literature documents which the researcher used as the framework for developing a professional development program for the instruction in the Nature of Science as listed below.

- 1) Thai science standards documents
- 2) The effective teacher development model
- 3) Approaches to teacher development based on the social constructivist perspective
- 4) The explicit approach for the Nature of Science instruction
- 5) The Nature of Science conceptual scheme and generally agreed characteristics for the Nature of Science instruction

These groups of documents were reviewed and discussed intensely in Chapter II, the Literature Review. Several guiding principles were derived from these

resources. They underpinned the program's objectives, contents, and teaching and learning activities.

According to the findings from the first phase of this research study and the theoretical framework from existing literature, five guiding principles of the program construct can be summarized and illustrated.

2.1 A program for in-service teacher professional development on instruction of the Nature of Science should aim to develop teachers' Nature of Science pedagogical content knowledge (NOS PCK).

The program should be designed to promote teachers' adequate understanding or conceptions of various aspects of the Nature of Science and the knowledge of how to teach those aspects of the Nature of Science effectively. Teachers should know how to use various instructional approaches, resources, and media to teach the topic of science content in a manner that helps students understand the target Nature of Science aspects.

The concepts of the Nature of Science which the participant teachers in this research should learn from the program are listed below.

a) Science is the seeking of approximate answers to questions about nature. It is a process that assists in making sense of the world. Science involves creating a body of knowledge using scientific processes to describe, explain and predict natural phenomena.

b) Scientific knowledge is a human construction. Scientists invent theories and laws from their minds, and scientific theories and laws are their best attempt to explain and describe a part of nature. There are many interpretations of nature and these interpretations constantly change with new experiences, concepts, and understanding of information discovered. Thus, scientific knowledge has a temporary status and should not be accepted as unquestionable truth.

c) Observations of the world are made through colored lenses built up as a result of prior knowledge, belief and theories.

d) There is no single method for performing science. Scientists use different methods according to circumstances. The scientific method is only one of those methods. Scientists can adjust their method of inquiry in the middle of an investigation and still get valid results.

e) New scientific knowledge is produced as a result of creativity and imagination coupled with scientific method.

f) Scientists study a world of which they are a part and as such their work is not objective or value free. A scientist is influenced by many factors, e.g. previous knowledge, logic and social factors. There could be contradictory conclusions from the same data because scientists interpret data in different ways and with different ideas.

g) Scientists and the scientific community generally display standards of openness of mind, honesty, circumspection, systematic working, collaboration, creativity, reason, perseverance, and responsibility. They are moral and ethical in their approach to their profession.

h) The communication and publication of scientific data for analytical and critical thinking increases scientific knowledge ceaselessly, and affects humanity in society and the environment.

i) Scientific knowledge is the important foundation of technology development. Technology is the process in any work or process of developing and improving products by using scientific knowledge in cooperation with other disciplines, skills, experiences, imaginations, and creativities of humanity.

The instructions of the Nature of Science which the participant teachers in this research should learn from the program are the explicit instructional approaches for the Nature of Science. The major teaching activities which should be introduced to teachers are listed below:

- i) Modeling behaviours, strategies, and language that reflect an understanding of the Nature of Science;
- ii) Addressing explicit and implicit views of the Nature of Science portrayed in activities;
- iii) Evaluating textbooks, audiovisual materials, and other curriculum materials for their accuracy in portraying the Nature of Science;
- iv) Modifying curriculum materials and activities so they more adequately portray the Nature of Science;
- v) Implementing timely historical examples that effectively convey a more accurate portrayal of the Nature of Science;
- vi) Ensuring that students have several experiences where they are *doing* science, and then *reflecting* on the process and what it implies about the Nature of Science;
- vii) Self-evaluating classroom performance as it pertains to an accurate portrayal of the Nature of Science;
- viii) Evaluating materials designed to assess student understanding of the social studies of science;

ix) Integrating a variety of formative assessments to continually monitor students' conceptions of significant issues in the Nature of Science (Clough, 1997: 200).

2.2 The design of activities within the program should be considered based on four specific aspects of developing teachers' understanding the Nature of Science instruction.

These aspects are developing teachers' understanding of the rationale behind the teaching of the Nature of Science; giving teachers' extensive experience in teaching and assessing the Nature of Science; giving teachers support in their field experiences; and developing teachers' intention to teach the Nature of Science explicitly (Abd-El-Khalick, Bell, and Lederman, 1998).

2.3 The program should be constructed based on the grounded perspective of social constructivism and should apply a teacher development model and approaches to teacher development based on the social constructivist perspective.

The program should adopt the perspective of both personal and social constructivist views of learning and use them as a referent for making decisions about learning opportunities for teachers participating in this program. From these perspectives, the teacher was viewed as a learner and teacher development was begun by consideration of what teachers already know; how this knowledge can be represented; and what experiences teachers should be provided with to enable them to add to their understanding of teaching and learning. Teachers were viewed as persons who "experience[d] teaching and learning situations and [gave] personal meaning to those experiences through reflection" (Tobin, Tippins and Gallard, 1994: 48). Teachers were also viewed as "professionals who think critically about themselves as practitioners and about contexts within which they work" (Gilbert, 1993: 21). They were "playing an active and creative role in the construction of experience; which all

knowledge development takes place in, and is dependent on, a social context” (Gilbert, 1993: 21).

The effective approaches to developing teachers should be the ways that can raise teachers’ reflection and help them to make judgments or adjustments to their values and practice. The collaborative teaching could be an effective approach to fostering teachers’ change, by questioning, problem-posing and working together in small collaborative groups (Gilbert, 1993).

From the constructivist perspective, the program should use the various learning methods and strategies to help teachers externalize their ideas or preconceptions, modify their ideas, and monitor and control their own learning. Teachers should have a chance to value their teaching competence and clarify any problematic aspect of their teaching within a supportive atmosphere. Teachers should be engaged in clarification of their existing concepts and beliefs about science education or the targeted topics of development; obtaining an input of new information; constructing new understanding; considering, weighing, evaluating, and accepting or rejecting the newly constructed understanding; using their newly accepted understanding in a variety of contexts. To develop classroom practice, teachers should gather new suggestions for teaching activities; considering them, visualizing, and planning for their use in the classroom; adapting and using new activities; sharing their classroom experiences with others and obtaining feedback about the use of the activities; evaluating the new teaching activities; and receiving support from facilitators, teacher colleagues, and their students.

2.4 The program should emphasize the explicit approaches for the Nature of Science instruction to serve as ‘conceptual tools’ for teachers’ elicitation and clarification of their existing conceptions as well as construction or reconstruction of their conceptions of the Nature of Science.

Teachers’ cognitive development in the Nature of Science concepts can be encouraged effectively by the use of an explicit approach for teaching the Nature of

Science in the teacher development program. This explicit approach can enhance teachers' construction or reconstruction of their understanding of the Nature of Science by their reflection on the activities in which they had engaged. These activities were the discussion about some aspects of the Nature of Science arising from reading assignments, science stories, or historical case studies, and participation in open-ended inquiry, investigation, or other practical work (Nott and Wellington, 1998a; 1998b).

2.5 The program should use the modeling of new teaching approaches, curriculum analysis and lesson planning, as well as classroom practice with facilitator and teacher colleagues' support and feedback to enhance teachers' NOS PCK and their classroom practice.

Teachers' classroom practice in the Nature of Science instruction can be enhanced by the use of the facilitator's modeling of the lessons within a science content course, science methods course, or real school classrooms. A teachers' appreciation of the importance of the Nature of Science and NOS PCK can also be enhanced by the teacher considering and analyzing the science curriculum; planning the Nature of Science lessons for their use in the classroom; sharing their classroom experiences with others; obtaining feedback about the use of the activities; and evaluating the new teaching activities. The facilitator can provide Nature of Science instructional materials and resources for supporting teachers' instruction (Clough, 1998; Bell, Lederman and Abd-El-Khalick, 2000; Schwartz and Lederman, 2002).

Program Features

1. Rationale of Program

An in-service primary school teacher professional development program on instruction of the Nature of Science was developed to help lower primary school teachers to teach science more effectively. The program aimed to develop teachers' understanding of the concepts and instructions of the Nature of Science. It was

believed that an understanding of the Nature of Science would help teachers and students understand the overview of science which would contribute to their interest in learning science and more effectively applying scientific knowledge in their real life contexts. Teachers who had an appropriate understanding of the Nature of Science tended to accept the idea of constructivist learning theory and applied teaching approaches based on this view to their teaching practice. The understanding of the Nature of Science could help teachers see the connection between real science or scientist science, school science or science education, and children's science (science from the students' perspective). Thus, teachers would be able to teach science with understanding.

This program adopted the assumption from research findings that teacher perceptions and beliefs about teaching and learning affect their actions as a teacher. It was believed that teachers "teach according to how [they] understand the nature of what [they] are teaching and according to how [they] understand the nature of learning" (Harlen, 1992 cited in Skamp, 2004; 31). The understanding of the nature of what teachers were teaching, at this point, referred to their understanding of the Nature of Science. This program emphasized that teachers should have an understanding of both the concepts and instructional approaches to the Nature of Science in order to be able to effectively enhance their students' understanding of the Nature of Science.

The concepts of the Nature of Science refer to the values and assumptions inherent in science, scientific knowledge, and the development of scientific knowledge which represent unique characteristics of science as describing and explaining what science is, how it works, how it is different from other disciplines, what the scientist has done in society throughout history, and how science and the scientist interact with society. These values and assumptions usually appeared in the form of statements relating to science, but were not scientific concepts or scientific knowledge.

This program assumed that every teacher already had their own view of science. The activities used in this program would help teachers express their own views of science and reflect on how their views affect their teaching and their students' views of science. The activities may support their current views or encourage them to modify or change these views. Through this program, teachers would be encouraged to develop appropriate and contemporary views of the Nature of Science in its five major aspects: a definition of science; the nature of scientific knowledge; the development of scientific knowledge; scientific attitudes; and the interrelation between science, technology, and society.

2. Objectives of the Program

In order to develop teachers' understanding and teaching of the Nature of Science, the program had specific objectives.

1. To enhance teachers' appreciation of the importance of the Nature of Science as instructional cognitive learning outcomes and their intention to teach it in the context of science subject matter, the in-service teachers will:

i. Assess and evaluate their own understanding of the concepts and instruction of the Nature of Science;

ii. Discuss and recognize the importance of the Nature of Science in their science teaching.

2. To develop teachers' understanding of the concepts of the Nature of Science by teachers' engagement in, discussion of, and reflection on learning activities based on explicit approaches for the Nature of Science.

3. To develop teachers' understanding of the instruction of the Nature of Science the in-service teachers will:

i. Analyze, discuss and reach conclusions about content strands and intended outcomes, teaching and learning processes, and assessments for the Nature of Science from the Manual of Content of Science Learning;

ii. Study the model lesson plans and learning materials designed based on the explicit instructional approach for the Nature of Science instruction within science content including case studies or vignettes of model teachers, analyze their advantages and disadvantages, modify and apply these lesson plans for their own classrooms, give reflections on these lesson plans;

iii. Discuss and generate the characteristics of good teaching approaches for the Nature of Science instruction for their classroom context;

iv. Reflect on the characteristics of good teaching approaches for the Nature of Science instruction for their classroom context and make decisions for further improvement.

3. Teaching and Learning Methods

This program adopts the perspective of both personal and social constructivist views of learning and uses it as a referent for making decisions about learning opportunities for teachers participating in this program. This program chose to use various learning methods and strategies to help teachers externalize their ideas or preconceptions, modify their ideas, and monitor and control their own learning. The major methods used were:

- Discussion;
- Collaboration;
- Self evaluation and reflection by journal writing;
- Activities based on explicit approaches for the Nature of Science including hands-on and minds-on activities and inquiry learning processes;
- Lesson plan design, implementation, and evaluation.

4. Learning Topics

The program had three major sessions with several sub-sessions. The names of each session and sub-session were as listed below.

1. Science and My teaching
 - 1.1 What is beneath the Teaching
 - 1.2 Science in Standards
2. Inquiry Activity
3. The Nature of Science in My Classroom
 - 3.1 Model Lesson Plans and Materials
 - 3.2 Good Teaching Approaches for My Own Context
 - 3.3 My Own Designs

5. Assessment of Program

The facilitator can assess and evaluate the program from;

1. Observe learners' participation in discussion, reflection, and presentation while engaging in activities. The learners should be able to perform according to the program's intended outcomes,
2. Assess the lesson plan designed according to the explicit instructional approach for the Nature of Science,
3. Journals of the learners which reflect their understanding of concepts and instruction of the Nature of Science gained from participating in the program
4. Pre and post-test and follow up interview for assess the learners' understanding of concepts and instruction of the Nature of Science gained from participating in the program

Table 4.1 below shows the objectives, major concepts, intended outcomes, and summary of activities of each session. An overview of the concepts and instructions of the Nature of Science emphasized in the program were summarized and shown.

Table 4.1 Program Objectives, Major Concepts, Intended Outcomes, and Summary of Activities

Session 1: Science and My teaching	
Objectives	<ul style="list-style-type: none"> • To appreciate the importance of NOS as the instructional cognitive learning outcomes and intend to teach it in the context of science subject matter
Major concepts	<ul style="list-style-type: none"> • Teachers teach according to how they understand the nature of what they are teaching and according to how they understand the nature of learning. Thus, teachers should think about what science is because they are going to teach it. • Teachers' preconceptions about NOS will be built into their views about learning science which will be contributing to their views on what it means for primary school students to learn science. • One of the aims for science education is to help students in thinking and working scientifically. "To develop an informed attitude toward science, it is necessary to have an idea of what 'science' is. Without this, attitudes will be formed on the basis of the many myths about science and about scientists" (Harlen, 1996: 37). • A useful starting point in an attempt to understand how scientists work is to acknowledge teachers' own and children's prior understanding of scientists or to elicit a personal framework of understanding about scientists and science. • The understanding of key concepts in science, understanding of evidence and science process skills, and competence in a range of skills in order to answer a question or solve a problem in their life scientifically will contribute to students being more likely to be scientifically literate. They will be able to take part in debate, make personal decisions or contribute to decisions in the local community and worldwide.
Sub-session: 1.1 What is beneath the Teaching	
Intended Outcomes	<ul style="list-style-type: none"> • Discuss and recognize the importance of NOS in their science teaching • Assess and evaluate their own understanding of the concepts and instructions of NOS
Activities	<ul style="list-style-type: none"> • Read an article about one Thai teacher who was promoted to have 'the best practice' in science teaching and discuss this teacher's view of science, teaching-learning science, and his teaching practices. • Discuss teachers' own views of science and teaching-learning science, and their teaching practices and compare to the best practice teacher's view. • Read the statement about "we teach according to how we understand the nature of what we are teaching and according to how we understand the nature of learning" (Harlen, 1992: 1). • Discuss and reach conclusions about NOS, the Nature of Learning Science, and influence of understanding of NOS in science instruction.

Table 4.1 (Continued)

Sub-session: 1.2 Science in Standards	
Intended Outcomes	<ul style="list-style-type: none"> Analyze, discuss and reach conclusions about content strands and intended outcomes, teaching and learning processes, and assessments for NOS from the Manual of Content of Science Learning.
Activities	<ul style="list-style-type: none"> Read the excerpt from the Thai science curriculum manual. Identify knowledge and skills which are recommended as the learning outcomes in the Thai science curriculum and discuss their importance. Discuss whether this knowledge and these skills are similar to or different from what scientists do and think in a real situation. Discuss and decide what scientists do and what scientists think or what the reasons behind their actions are. Read the 'Inquiry Story' and articles of recent scientists' work, discuss and identify the contemporary view of NOS and the relationship between NOS and science curriculum
Session 2: Inquiry Activity	
Objectives	<ul style="list-style-type: none"> To develop teachers' understanding of the concepts of NOS by teachers engagement in, discussion of, and reflection on learning activities based on explicit approaches for the Nature of Science. To develop teachers' understanding of the instruction of NOS.
Major concepts	<ul style="list-style-type: none"> The activity design based on an explicit approach to teaching NOS could help teachers to recognize and understand some contemporary concepts of NOS as listed below. <ul style="list-style-type: none"> Scientific knowledge is partly a product of human inference, imagination, and creativity. Scientific knowledge is, ultimately, empirically based (i.e., based on and/or derived from experiment and observation). Scientific knowledge (both theories and laws) is tentative and subject to change. The scientific method is only one of those methods. Scientists can adjust their method of inquiry in the middle of an investigation and still get valid results. A scientist is influenced by many factors, e.g. previous knowledge, logic and social factors. The activity design based on an explicit approach to teaching NOS could help teachers to develop understanding and skills of some science process skills as listed below. <ul style="list-style-type: none"> Knowing the distinction between observation and inference Hypothesizing Planning and developing ways to test hypotheses Collecting and manipulating data An explicit approach to teaching NOS is useful in developing teachers' understanding of NOS. To provide them with an opportunity to engage in scientific inquiry and/or investigation and communicate concepts of NOS explicitly would help students in developing their understanding of NOS. Thus, teachers should be willing to use this explicit approach with their own students.

Table 4.1 (Continued)

Session 2: Inquiry Activity	
Intended Outcomes	<ul style="list-style-type: none"> • Discuss and identify some aspects of the concepts of NOS from the activity. • Discuss and reflect on activities in order to modify and apply these model lessons for their own classrooms. • Develop some science process skills and inquiry skills for their lower primary school science teaching.
Activities	<ul style="list-style-type: none"> • Engage in activities based on the teaching and learning activities of ‘Rediscovering Historical Experiments’ (Kipnis, 1998). • The activities were composed of: <ul style="list-style-type: none"> ○ Introduction: Discuss factors which cause objects to free fall and what makes them have different velocities when falling. ○ Present initial ideas: Read brief biographies about Aristotle and Galileo, and their two different explanations. ○ Discuss to choose idea: Discuss and make a decision to accept and reject one of two explanations. ○ Doing experiments for testing hypothesis: Design and do experiments for testing Aristotle’s explanation or Galileo’s explanation by using ‘Investigation Planning Board’ ○ Discussion: Discuss scientific concepts and the conceptions of the NOS gained from doing experiments, read more articles of Aristotle’s biography and scientists’ experiments on free falling objects throughout history, discuss relationship between science, technology, and society • Discuss and identify an explicit approach to teaching NOS which was modeled through the activities and application of this approach in their science classes.
Session 3: The Nature of Science in My Classroom	
Objectives	<ul style="list-style-type: none"> • To develop teachers’ understanding of the instruction of NOS
Major concepts	<ul style="list-style-type: none"> • By participating in activities in this session, teachers should recognize “the General Characteristics of Explicit Approach for Teaching NOS” as listed below: <ol style="list-style-type: none"> 1. Setting explicit cognitive instructional outcomes for understanding of NOS concepts; 2. Modeling behaviors, strategies, and language that reflect an understanding of NOS; 3. Addressing explicit and implicit views of NOS portrayed in activities; 4. Evaluating textbooks, audiovisual materials, and other curriculum materials for their accuracy in portraying NOS; 5. Modifying curriculum materials and activities so they more adequately portray NOS; 6. Implementing timely historical examples that effectively convey a more accurate portrayal of NOS; 7. Ensuring that students have several experiences where they are <i>doing</i> science, and then <i>reflecting on</i> the process and what it implies about NOS;

Table 4.1 (Continued)

Session 3: The Nature of Science in My Classroom	
Major concepts	<p>8. Self-evaluation of classroom performance as it pertains to an accurate portrayal of NOS;</p> <p>9. Evaluating materials designed to assess student understanding of the social studies of science;</p> <p>10. Integrating a variety of formative assessments to continually monitor students' conceptions of significant issues in NOS (Clough, 1997: 200; Lederman, 1998; 1999; Robinson, 1968).</p> <ul style="list-style-type: none"> • Teachers should recognize that all of these general characteristics could be embedded in various teaching and learning activities such as hands-on activities and practical work; laboratory activities and experimental work; inquiry oriented instruction e.g. learning cycle, guided inquiry and open-ended inquiry; using stories e.g. science stories, historical case studies, and controversy issues. • Teachers should also recognize that the most important part of teaching NOS by explicit approach is to address NOS concepts which are portrayed in activities and encourage students to reflect on their understanding of these concepts.
Sub-session: 3.1 Good Teaching Approaches for My Own Context	
Intended Outcomes	<ul style="list-style-type: none"> • Discuss, recognize, clarify and reflect on the characteristics of good teaching approaches for NOS instruction for their classroom context.
Activities	<ul style="list-style-type: none"> • Clarify and assess their own science teaching by using 'A General Map of Personal Professional Development Possibilities in Primary School Science'. • Discuss and identify the characteristics of good science teaching included in NOS instruction. • Develop the criteria for assessing science teaching based on characteristics of good science teaching, and develop assessment tools.
Sub-session: 3.2 Model Lesson Plans and Materials	
Intended Outcomes	<ul style="list-style-type: none"> • Analyze the advantages and disadvantages, modify and apply the model lesson plans and learning materials based on the explicit instructional approach for NOS instruction in their own classrooms
Activities	<ul style="list-style-type: none"> • Study the model lesson plans and learning materials. • Discuss their advantages and disadvantages by using the assessment tools which they have developed • Modify & apply model lesson plans and materials • Prepare for microteaching • Do microteaching with peer review 15-20 min./ person • Assess and reflect on their science teaching in the microteaching using the assessment tools

Table 4.1 (Continued)

Sub-session: 3.3 My Own Designs	
Intended Outcomes	<ul style="list-style-type: none"> • Design, implement, and assess their own lesson plans and learning materials based on the characteristics of good teaching approaches for NOS instruction for their classroom context. • Reflect on the characteristics of good teaching approaches for NOS instruction for their classroom context and make decisions for further improvement.
Activities	<ul style="list-style-type: none"> • Revise the modified lesson plans and materials. • Discuss and design action research questions for the implementation of modified lesson plans in real classroom context. • Discuss and reflect on the implementation of their own lesson plans and materials. • Assess advantages and disadvantages by using the criteria for assessing science teaching based on characteristics of good science teaching. • Design the further improvement of their teaching in this topic of modified lesson plans. • Discuss and revise the characteristics of good science teaching for their own context. • Revise the criteria of the assessment tools which they have developed. • Identify what has been learnt from the program about NOS & teaching science. • Discuss making decisions for further improvement in their own teaching.

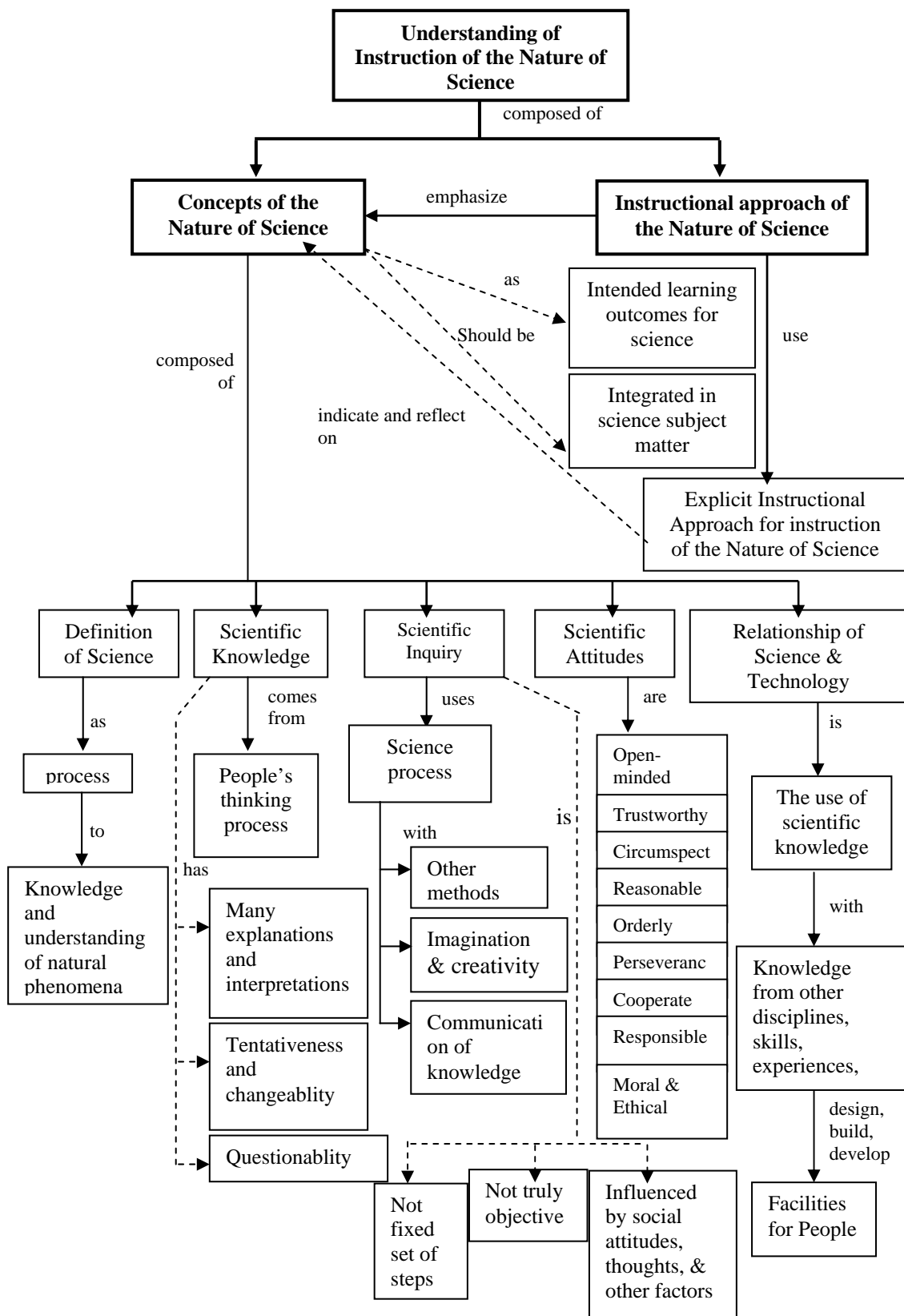


Figure 4.1 An Overview of the Concepts and Instructions of the Nature of Science Emphasized in the Program

Validation of the Program

An in-service primary school teacher professional development program on the instruction of the Nature of Science was first developed in an English version under the supervision of two New Zealand science educators. The program was composed of three documents including the program outline, facilitator information sheets, and teacher activities and notebook. These documents were later translated into a Thai version. The program design and activities with its documents were audited by three Thai science educators for their appropriateness with Thai primary school teachers.

The program design and activities with its documents were improved in three major aspects. Firstly, the article of one Thai teacher who was promoted as having 'the best practice' in science teaching was added into the sub-session 1.1. This new article replaced the article of Teachers' Scenario: Mrs. Constancy and Mrs. Amender which was designed to initiate teachers in discussion on their view of science, teaching-learning science, and teaching practices. The new article seemed to be more familiar and interesting to Thai teachers who would participate in the program rather than the Teachers' Scenario which was imported from western culture. Secondly, the activities based on the teaching and learning activities of 'Rediscovering Historical Experiments' developed by Kipnis (1998) was used in session 2. These activities replaced the activities which were based on the teaching and learning activities of 'Black-Box Activities' developed by Lederman and Abd-El-Khalick (1998). The activities based on 'Black-Box Activities' were good at modeling the teaching and learning scientific process skills to explicitly convey concepts of the Nature of Science. However, these activities were "designed at a level of generality" (Lederman and Abd-El-Khalick, 1998:84). They did not convey any scientific concepts or knowledge. The new activities were considered as more suitably modeled activities for teachers who participated in the program. This was because they could model teaching and learning science by integrating scientific concepts or knowledge with scientific process skills, and conceptions of the Nature of Science. Finally, a concluding diagram of learning topics and a concept map of overall major concepts of

the program were developed and added into the program outline, facilitator information sheets, and teacher activities and notebook. This diagram and the concept map showed the overview of the documents in more easily readable form.

Program Implementation Process, Context, and Factors Affecting It

Before implementing the program, the researcher had negotiated with the school's administrator of the teacher participants to ask them to set an in-service training program within the school. The administrator allowed the researcher to set an after school training course on every Monday and Tuesday afternoon around 4.00-5.30 pm, using the science laboratory room. The school also asked the researcher to open this program for other non-participant for attendance by teachers who taught in the same Grade as the participant teachers. Thus, there were, in total, nine Grades 1 and Grade 2 teachers joining in the program. All of these teachers, including the four participant teachers, were general teachers who taught science as one of the core subjects in the 2005 academic year. The program was organized into 12 sessions with approximately 90 minutes per session based on the program features. The setting of the training room is illustrated in Figure 4.2 below.

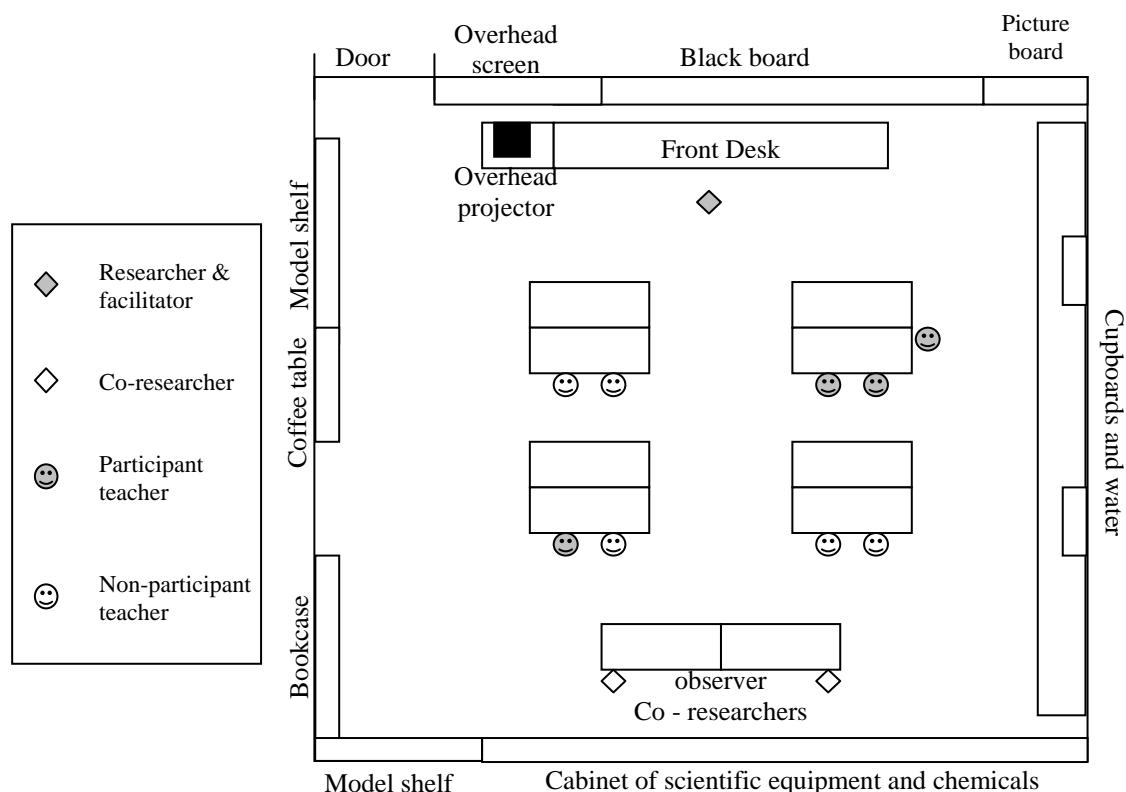


Figure 4.2 Training Room in Participant School

During the implementation, the researcher tried to keep following the planned task which had been designed previously. From the interaction with teachers who were participating in the program, the researcher found that the program schedule and activities had to be flexible and change according to the teachers' needs, preferences, and learning abilities. The factors and context which affected the researcher's decision in changing program schedules and activities gradually could be summarized into two major aspects: the teacher's learning styles and school events.

1. Teachers' learning styles

It was found that teachers who attended the after-school training program were more than 35 years old. They seemed to need a longer period of time to read, write, and generate their ideas when doing activities. Sometimes, teachers could not finish

the activities completely within one period. Thus, the researcher as facilitator had to revise the same activity and conclude it in the next session.

Teachers did not have a willingness to prepare science lesson plans, do any homework, or any extra reading and writing. They gave as reasons that they had many subjects to teach and science was not their major. They also had much work and many documents to attend to both in school and at home. It was also found that sometimes teachers forgot to prepare or bring some training documents and material which the facilitator required for the course. Thus, the researcher had to try to finish every lesson and activities within training session.

It was found that teachers seemed to prefer the hands-on activities with discussion rather than reading and lecturing. In the first period, the researcher found that teachers seemed to be bored because the reading and discussion seemed to be a passive activity. Thus, in the second session, the researcher designed and introduced a new activity as a game of balancing a mobile of two different sizes and weight. This activity was used to introduce the lesson about the problem-solving process. Following that, teachers seemed to be more eager in doing activities.

It was found that the training atmosphere was friendly and supportive. This was because teachers already knew one another. They sometimes dallied with their peers and facilitator while doing some hands-on activities, presentation in front of the class, or discussion. It was also found that when the training program took more sessions, teachers seemed to share more ideas and feelings with the facilitator.

2. School events

The training program was held in the second semester of the 2005 academic year. It was found that the school had many after-school events for which teachers had responsibilities. For example, there were school meetings, Boy Scouts camping, Sports Day, school evaluation for quality assurance, and mid-term examinations. Most of the teachers, including participant teachers, needed time for preparation of

documents or materials and to participate in those activities. These events had an effect on the training program time schedule, especially from the sixth session to the twelfth session. Sometimes teachers asked to skip some training sessions in some weeks and move to the next one or two weeks. The overall training time was expanded to become more than six weeks. For the last three sessions, teachers all agreed to join these into a half day training session. Thus, the tenth to twelfth sessions were held on one Saturday afternoon. The training activities occurring within each session are summarized in Table 4.2 as follows.

Table 4.2 Summary of Training Activities of the Program Implementation

Period	Activities
1	<ul style="list-style-type: none"> • Introduced program aims and outline of activities • Session: 1 Science and My teaching <ul style="list-style-type: none"> ○ Read an article describing one Thai teacher who was promoted as having ‘the best practice’ in science teaching ○ Discuss each teacher’s personal view of science, teaching-learning science, and teaching practices
2	<ul style="list-style-type: none"> • Session: 1 Science and My teaching (continued) <ul style="list-style-type: none"> ○ Solve the problem of balancing a mobile with two different sizes and weights and compare the solving process with scientist’s work ○ Read the ‘Inquiry Story’ and articles of recent scientists’ work, discuss and identify concepts of contemporary view of NOS
3	<ul style="list-style-type: none"> • Session: 2 Inquiry Activity <ul style="list-style-type: none"> ○ Do ‘Rediscovering Historical Experiments’ activities <ul style="list-style-type: none"> ▪ Introduction: Discuss factors which cause objects to free fall and why they have a different velocity while falling ▪ Present initial ideas: Read about two different explanations from Aristotle and Galileo including their brief biographies. ▪ Discuss and choose idea: Discuss and make a decision to accept or reject one of these two explanations ▪ Design experiments for testing hypothesis: Design experiments for testing Aristotle’s explanation or Galileo’s explanation by using ‘Investigation Planning Board’ and present the design for peers review
4	<ul style="list-style-type: none"> • Session: 2 Inquiry Activity (continued) <ul style="list-style-type: none"> ▪ Do experiments for testing hypothesis: Design experiments for testing Aristotle’s explanation or Galileo’s explanation by using ‘Investigation Planning Board’ ▪ Discuss and reach conclusions from the findings: Discuss and identify the results which were found from doing experiments ▪ Discussion: Discuss scientific process and process skills used in doing experiments

Table 4.2 (Continued)

Period	Activities
5	<ul style="list-style-type: none"> • Session: 2 Inquiry Activity (continued) <ul style="list-style-type: none"> ▪ <i>Discussion (continued):</i> <ul style="list-style-type: none"> - Review the findings of experiment in the last period - Read and discuss more articles of Aristotle’s biography and scientists’ experiments on free falling objects throughout history - Discuss and reach conclusions about the conceptions of the NOS gained from doing experiment & reading articles. ○ Discuss and reach conclusions about how teachers can develop students’ conceptions of NOS ○ Discuss and reach conclusions about the an explicit approach to teaching NOS which was modeled through the activities
6	<ul style="list-style-type: none"> • Session: 3 The Nature of Science in My Classroom <ul style="list-style-type: none"> ○ Review the concept map of NOS concepts summarized from previous period ○ Discuss and reach conclusions about five major aspects to consider when teaching science ○ Study ‘A General Map of Personal Professional Development Possibilities in Primary School Science’, answer the questions from the map and discuss teachers’ own science teaching
7	<ul style="list-style-type: none"> • Session: 3 The Nature of Science in My Classroom (continued) <ul style="list-style-type: none"> ○ Review five major aspects to consider when teaching science ○ Discuss each teacher’s personal views of science and aims of science teaching ○ Read the excerpt from Thai science curriculum manual ○ Discuss the aims of Thai science education ○ Discuss students’ learning of science ○ Discuss summary and present characteristics of good science teaching approaches from their personal perspectives
8	<ul style="list-style-type: none"> • Session: 3 The Nature of Science in My Classroom (continued) <ul style="list-style-type: none"> ○ Review characteristics of good science teaching approaches from teachers’ perspectives ○ Study model criteria and assessment tools for science teaching ○ Select and apply criteria to make their own assessment tools for science teaching
9	<ul style="list-style-type: none"> • Session: 3 The Nature of Science in My Classroom (continued) <ul style="list-style-type: none"> ○ Review assessment tools for science teaching which teachers had developed ○ Study model lesson plans ○ Conclude the explicit approach to teaching NOS conveyed in sample lesson plans
10	<ul style="list-style-type: none"> • Session: 3 The Nature of Science in My Classroom (continued) <ul style="list-style-type: none"> ○ Review aims of science teaching and characteristics of good science teaching approaches ○ Discuss the importance of teaching NOS ○ Study model lesson plan and summarize NOS concepts and characteristics of an explicit approach to teaching NOS which is embedded in this lesson plan

Table 4.2 (Continued)

Period	Activities
11	<ul style="list-style-type: none"> • Session: 3 The Nature of Science in My Classroom (continued) <ul style="list-style-type: none"> ○ Design lesson plan which focuses on developing students' scientific concepts, NOS concepts, science process skills and scientific attitudes
12	<ul style="list-style-type: none"> • Session: 3 The Nature of Science in My Classroom (continued) <ul style="list-style-type: none"> ○ Present lesson plan with facilitator and peer review

In the first session, the facilitator aimed to help teachers clarify their prior knowledge or their existing view of science and science education. An article about one Thai teacher who was promoted as having 'the best practice' was used as a tool to initiate the discussion. It was found that after teachers read this article they started to discuss the aim of their science teaching. The aim of best practice teacher was to develop students to be scientists which seemed to be different from the ideas of teachers who attended the training program. Thus, this conflict seemed to be a good starting point for the discussion.

The activity of balancing a mobile with two different weights was designed and used to initiate teachers' understanding of the problem-solving process and lead to the discussion of what scientists do. The 'Inquiry Story' and articles of recent scientists' work were used as tools to construct teacher's contemporary conception of scientific inquiry. Teachers were assigned to work in pairs or in groups of three to summarize what scientists do from the article. The facilitator also used this period to model the explicit instructional approach for the instruction of the Nature of Science. After completing the activity of balancing the mobile, the facilitator started to ask reflective questions for teachers to compare what they did with scientists' activities and started to think about scientific inquiry. Teachers were asked 'How is this problem-solving process similar to a scientist's process?' After reading and analyzing the articles, the facilitator asked the question for teachers to reflect on; 'What more do you know about science and scientists?'

The third to the fifth sessions were designed to develop teachers' understanding of scientific process, scientific process skills, and the interrelationship

between science, technology, and society. The facilitator also aimed to model the explicit instructional approach for the instruction of the Nature of Science based on 'Rediscovering Historical Experiments' activities. Teachers were assigned to work in pairs or in groups of three for these activities. In the post-experiment discussion section, the facilitator asked a question for teachers to compare what they did with scientists' activities. The reflective question was; 'Did we do activities similar to scientists?'

From the fourth session until the twelfth session, the activities were designed for teachers to link the concepts of the Nature of Science and explicit instructional approaches for the Nature of Science to their classroom practices. There were whole class discussions about the aims of Thai science education and the relationship between the characteristics of good science teaching approaches and the aims of science education and the Nature of Science. There was an example of assessment tools for science instruction which included items for assessing the instruction of the Nature of Science. The facilitator also provided three sample lesson plans which were based on the explicit instructional approaches for the Nature of Science. These tools and lesson plans were used as the guideline for teachers to see how to apply the concept of the Nature of Science and explicit instructional approaches for the Nature of Science to the classroom. Finally, teachers were to design their lesson plan and present it in front of the class personally with facilitator and peers reviewing it.

Summary

An in-service primary school teacher professional development program on instruction of the Nature of Science was developed based on the findings of the first phase of the research and the theoretical framework from existing literature. The objectives of the program were to enhance teachers' appreciation of the importance of the Nature of Science as instructional cognitive learning outcomes and their intention to teach it in the context of science subject matter; to develop teachers' understanding of the concepts of the Nature of Science by engagement in, discussion of, and reflection on learning activities based on explicit approaches for the Nature of

Science; and to develop teachers' understanding of the instruction of the Nature of Science. The program design and activities were developed based on the explicit approaches for the Nature of Science instruction and approaches to teacher development based on the social constructivist perspective. After the program was developed, the researcher implemented it personally, and acted as a facilitator. There were two co-researchers helping to record data in the program implementation. The program was organized as an after-school training program with 12 sessions of approximately 90 minutes per period. The program schedule and activities had to be flexible and changed often according to the teachers' needs, preferences, and learning abilities. Two major factors affecting the training program were the teachers' learning style and school events. The facilitator used explicit instructional approaches during Sessions 1 and 2 of the program. This was to develop teachers' conceptions of the Nature of Science and modeled the instructions for the Nature of Science. In Session 3 of the program, the concepts of the Nature of Science and the explicit instructional approaches for the Nature of Science were summarized and indicated. Teachers studied the sample assessment tools for science teaching and sample lesson plans. Teachers were also assigned to design and present their own lesson plan with facilitators and reviewing peers. These were so they could have guidelines and understanding to apply the explicit instructional approaches for the Nature of Science to their science class.

The next chapter will present the findings from the first and the third phases of the research study. These findings will be shown in the form of each participant teacher's profile of their understanding and teaching of the Nature of Science before, during, and after attending the training program. Then, the cross case findings will be presented in the aspects of teacher's understanding and teaching of the Nature of Science, factors affecting their teaching, and their perspectives of the training program.

CHAPTER V

RESULTS

This chapter presents the findings from the first and third phases of the research. The findings of each participant teacher from these two research phases were gathered and organized in the form of each teacher's profile. This profile composed of teacher's background and participation in the program; understanding and teaching of the Nature of Science before, during and after attending the training program; factors affecting teaching; and perspectives on the training program. This chapter also presents the findings across four cases of participant teachers. These cross cases findings will help identify the effectiveness of an in-service professional development program on the instruction of the Nature of Science.

The Profiles of Each Participant Teacher

1. Case 1: Ms. Dara

1.1 Background and Participation in the Training Program

Ms. Dara (pseudonym) was a Grade 1 classroom teacher and took responsibility in the department of evaluating and assessing student performance in her school. She graduated from a faculty of Education, majoring in teaching Thai language. She had more than 15 years experience of teaching all groups of subjects including Life Experience subjects, into which science had been integrated. Because of the new Thai science curriculum and recent educational reform policy, as well as the lack of a science specialist teacher in her school, in the 2004 academic year, Ms. Dara had to teach science as an individual core subject for the first time. Before the 2004 academic year, she had never attended any training courses for science teaching. However, she has tried to improve her teaching by observing her peers while teaching science. In the questionnaire, she responded that she felt neutral about science because

she did not have a good background in studying science. She also did not like to teach science because of a lack of expertise in teaching and a lack of ability in “transmitting” the knowledge of science (statement in the open-ended part of the questionnaire). However, when interviewed, she mentioned that she tried to make it fun when teaching science so that her students would love and enjoy studying science.

In the 2005 academic year, Ms. Dara was a Grade 1 classroom teacher and taught in the same classroom as in the 2004 academic year. She taught all subjects including science. She taught science two periods per week. Ms. Dara attended the first sessions of the training program, but missed the last four sessions. She always took part in sharing ideas in the discussions and answering the questions. She intended to do every activity which she attended. When working in groups or in a pair, she usually worked with Ms. Napar. She was always the presenter in front of the class for her group.

1.2 Teacher’s Understandings of the Concepts of the Nature of Science

From the statistical analysis of the whole rating scale part of NOSI questionnaire, Ms. Dara’s mean score of all question items before and after attending the training program is summarized and shown in Table 5.1 below.

Table 5.1 Ms. Dara’s Mean Score of all Question Items Before and After Attending the Program

Academic Year	Period	Mean Score
2004	Before the Program	3.696
2005	At the first session of the Program	4.038
	After the Program	4.231

From the mean scores, it could be inferred that, on the whole, before attending the training program Ms. Dara had a contemporary view of the concepts of

the Nature of Science. After attending the program, she had a more contemporary view of the concepts of the Nature of Science.

Ms. Dara's responses to 29 rating scale items of the Nature of Science statements before and after attending the program are shown in Table 5.2 below. 'X' refers to the position of her agreement on the rating scale before and after attending the program. It also refers to her point of view on each statement in the range of traditional to contemporary view or in the range of misconception to right conceptions. 'O' refers to the position of her agreement on the rating scale in the first training session. If her agreement both at the first training period and after the program are in the same position, the symbol, '⊗' is presented.

Table 5.2 Ms. Dara' s Responses to the Nature of Science Statements Before and After Attending the Program

	Statements	Strongly agree	agree	Neutral	disagree	Strongly disagree
1	Science is only a body of knowledge which explains concrete things, natural phenomena, and the world around us.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----O-----X→				
2	Science is a process of exploring the unknown and discovering new things about our world and universe and how they work.	Contemporary			Traditional	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←⊗-----→				
3	Science is inventing and designing things and finding out ways to make people's lives better.	Misconception Naïve		Right		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		← X-----O→				
4	Scientific knowledge is discovered by scientists who make observations of the world and carefully record and organize the facts or truths in a systematic way.	Traditional		Contemporary		
		<i>Before</i>				
		←X-----→				
		<i>At 1st Period & After</i>				
		←⊗-----→				
5	Scientific knowledge is generated by scientists who attempt to explain and predict the natural phenomena, based on empirical evidence and logical reasoning.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		← X-----O-----→				

Table 5.2 (Continued)

	Statements	Strongly agree	agree	Neutral	disagree	Strongly disagree
6	We can trust in scientific knowledge because it is confirmed by scientific method, scientific experiments and approved by the scientific community.	Contemporary		Traditional		
		Before				
		←-----X-----→				
		At 1 st Period & After				
		←⊗-----→				
7	The terms facts, concepts, principles, laws and theories in science have the same meaning as when used in our daily lives.	Misconception	Naïve	Right		
		Before				
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				
8	Scientific facts come from observation and experiment, and then, always become scientific theories that, in turn, become laws.	Misconception	Naïve	Right		
		Before				
		←-----X-----→				
		At 1 st Period & After				
		←⊗-----→				
9	We can not have questions about scientific theories and laws. They are 100% true according to reality and unchangeable. We have to remember and use them.	Traditional		Contemporary		
		Before				
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				
10	When scientists make arguments, they are not influenced by their personal bias.	Traditional		Contemporary		
		Before				
		←-----X-----→				
		At 1 st Period & After				
		←-----X-----O-----→				
11	Scientific knowledge can change if there is more evidence.	Contemporary		Traditional		
		Before				
		←X-----→				
		At 1 st Period & After				
		←⊗-----→				
12	We make sense of the world by careful and systematic study in order to make a reasonable explanation of phenomena.	Contemporary		Traditional		
		Before				
		←X-----→				
		At 1 st Period & After				
		←⊗-----→				
13	The world and universe occur in consistent patterns. We can discover these patterns by using the intellect and with the aid of instruments.	Traditional		Contemporary		
		Before				
		←-----X-----→				
		At 1 st Period & After				
		←X-----O-----→				
14	Science is the most powerful way of understanding and discovering the truth of the natural world.	Traditional		Contemporary		
		Before				
		←X-----→				
		At 1 st Period & After				
		←⊗-----→				
15	Some matters cannot be examined usefully in a scientific way.	Contemporary		Traditional		
		Before				
		←-----Do not understand-----→				
		At 1 st Period & After				
		←X-----O-----→				

Table 5.2 (Continued)

	Statements	Strongly agree	agree	Neutral	disagree	Strongly disagree
16	Science can not completely explain the world and how it works, but, it can give accurate approximations.	Contemporary		Traditional		
		Before				
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				
17	Scientists have no ideas about results before doing observations or experiments.	Traditional			Contemporary	
		Before				
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				
18	Scientists do experiments to confirm scientific knowledge so as to prove the truth or falsehood of this knowledge.	Traditional			Contemporary	
		Before				
		←X-----→				
		At 1 st Period & After				
		←⊗-----→				
19	Every scientist always does scientific investigations in the same way, as a fixed set of steps, to gain scientific knowledge.	Traditional			Contemporary	
		Before				
		←X-----→				
		At 1 st Period & After				
		←-----O-----X→				
20	Scientists try to explain and predict phenomena as the most accurate reflection of reality, although they know that they can not discover the absolute truth.	Contemporary			Traditional	
		Before				
		←X-----→				
		At 1 st Period & After				
		←⊗-----→				
21	We can not use imagination and creativity to achieve scientific knowledge.	Traditional			Contemporary	
		Before				
		←-----X-----→				
		At 1 st Period & After				
		←-----O-----X→				
22	Scientists need to communicate their scientific results and require peer review.	Contemporary			Traditional	
		Before				
		←-----Do not understand -----→				
		At 1 st Period & After				
		←⊗-----→				
23	Scientists always work individually in the laboratory and social affairs outside do not affect their work.	Traditional			Contemporary	
		Before				
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				
24	Scientists are people like every body and participate in community both as specialists and as citizens.	Contemporary			Traditional	
		Before				
		←X-----→				
		At 1 st Period & After				
		←⊗-----→				
25	Science and technology affects society on the one hand, society affects science and technology on the other hand.	Contemporary			Traditional	
		Before				
		←X-----→				
		At 1 st Period & After				
		←⊗-----→				
26	Technology gets ideas from science and science gets new processes and instruments from technology.	Contemporary			Traditional	
		Before				
		←-----Do not understand -----→				
		At 1 st Period & After				
		←⊗-----→				

Table 5.2 (Continued)

	Statements	Strongly agree	agree	Neutral	disagree	Strongly disagree
27	Scientists can do scientific research but do not have to consider ethical principles.	<i>Traditional Before</i>		<i>Contemporary</i>		
		←-----X→				
		<i>At 1st Period & After</i>				
		←-----⊗→				
28	Science is scientists' work only. Other groups of people in society can not participate.	<i>Traditional Before</i>		<i>Contemporary</i>		
		←-----X→				
		<i>At 1st Period & After</i>				
		←-----⊗→				
29	Today scientists develop scientific knowledge from previous knowledge according to history.	<i>Contemporary Before</i>			<i>Traditional</i>	
		←X-----→				
		<i>At 1st Period & After</i>				
		←⊗-----→				

Ms. Dara's conceptions of the Nature of Science before, during and after attending the program are described in detail below within the five major aspects of the Nature of Science: definitions of science, scientific knowledge, development of scientific knowledge, and the interrelations of science, technology and society.

1.2.1 Definitions of Science

Before attending the program, Ms. Dara's responses to NOSI questionnaire items 1 and 2, in Table 5.2, showed that she agreed with both traditional and contemporary views of the definitions of science. Thus, it could be inferred that she had mixed or blended view of the definition of science. She seemed to view science as both a body of knowledge and a process for understanding the world.

In the open-ended part of the questionnaire, Ms. Dara mentioned the subject of science as being related to a process of knowledge inquiry by observation, exploration, investigation, and systematic research.

In the semi-structured interview, Ms. Dara was asked: *Based on the Nature of Science or the science subject, what is the meaning or definition of science?* Her answer was:

... Science must make students learn by emphasizing process, right? Learning in process... Students must know about observation, analysis, and synthesis... [in science] has observation, analysis, synthesis, and application (Ms. Dara).

From the answer, she seemed to view science as a process and she also gave her answer by defining science education or giving the definition of science from a teacher's perspective. She seemed to adopt a contemporary view of science as a process in her classroom teaching rather than a traditional view of science as a body of knowledge.

The questionnaire response found that Ms. Dara agreed that science is inventing and designing things and finding out ways to make people's lives better (item 3). Thus it could be inferred that Ms. Dara had an alternative conception of the differences between science and technology. She seemed to view science in terms of technology. It could also be inferred that she might have a utilitarian view which holds that the aim of science is to help find ways to make people's lives better.

In the first session of the program, there was a discussion about each teacher's personal view on science and teaching science. It was found that Ms. Dara's expressed personal idea was that science was unfinished learning and teaching. It was renewed and changed all the time. Teachers had to catch up with science so they could teach it. Thus, she seemed to view science as a subject to be taught, and recognized the tentativeness of science.

After attending the program, it was found that Ms. Dara changed to strongly agree with the contemporary view of the definitions of science as she responded to items 1 and 2. It could be inferred that after attending the program Ms. Dara had a contemporary view of the definitions of science. She seemed to view science as a process to understand the world.

The questionnaire response after attending the program also found that Ms. Dara changed to strongly agreeing that science is inventing and designing things and finding ways to make people's lives better (item 3). From this it could be inferred that after attending the program, Ms. Dara had a misconception of the differences between science and technology. She seemed to view science in terms of technology. It could also be inferred that she might have a utilitarian view which holds that the aim of science is to help find ways to make people's lives better.

1.2.2 Scientific Knowledge

(1) Source of Scientific Knowledge

In Table 5.2, before attending the program, Ms. Dara's responses to questionnaire items 4 and 5 showed that she agreed with both items. This could mean that Ms. Dara strongly agreed that scientific knowledge was discovered by scientists through observation and scientific method, at the same time she agreed that scientific knowledge was also generated by scientists through their processes of thought, based on empirical evidence. Thus, she had mixed traditional and contemporary views of the source of scientific knowledge considering that it came from both discovery and generation by scientists.

In the semi-structured interview, Ms. Dara was asked that: *How could scientists gain scientific knowledge?* Her answer was:

... It [scientific knowledge] may firstly come from learning by oneself, from experiences. That is experiences sometimes teach us automatically... As children, sometimes they haven't learnt from us yet, but they can tell some stories or something to us. This is because they have experiences, their own direct experiences. They would learn science unconsciously. I think that scientists may be like that, learning from experiences... (Ms. Dara).

It could be seen that Ms. Dara emphasized that scientists might gain scientific knowledge primarily from learning by themselves and from direct experiences similar to the way young children learn from their own experiences.

In the second session of the program, there was a discussion about how much more teachers knew about science and scientists after doing activities. Ms. Dara mentioned that she knew more about how scientists investigated for scientific data. In the fifth session of the program, there was a discussion to summarize conceptions of the Nature of Science gained from doing experiments and reading the articles. Ms. Dara mentioned that scientific knowledge came from the inquiry process and data gathering.

After attending the program, responses to questionnaire items 4 and 5 showed that Ms. Dara strongly agreed with the traditional view and agreed more with the contemporary view of the source of scientific knowledge. Thus, she seemed to view that scientific knowledge as coming from both discovery and generation by scientists.

(2) Nature of Scientific Knowledge

There are three sub-points of the nature of scientific knowledge focused on in this research.

i) Validity of Scientific Knowledge

Before attending the program, Ms. Dara's response to a statement about validity of scientific knowledge on the NOSI questionnaire is shown in item 6 of Table 5.2. It was found that she agreed with the contemporary view which emphasized validity of scientific knowledge as being based on both confirmation of empirical evidence through scientific method and experiments, and approval of the scientific community.

It was found that after attending the program, she still strongly agreed with the contemporary view which emphasized that validity of

scientific knowledge is based on both confirmation of empirical evidence through scientific method and experiment, and approval of scientific community.

ii) Definitions of Different Kinds of Scientific Knowledge

Before attending the program, Ms. Dara's responses to statements about different kinds of scientific knowledge on the NOSI questionnaire are shown in items 7 and 8 of Table 5.2. Ms. Dara chose the neutral response to item 7. This could mean that she had a naïve understanding about the difference between using the words facts, concepts, principles, laws and theories in science and using these words in daily life. This finding correlated with her own interview response where she had tried to explain these scientific words from her classroom practices. From her answer to item 8 it could be inferred that she had an alternative conception that scientific facts could be simply developed to become scientific theories which then turn become scientific laws.

In the semi-structured interview, Ms. Dara was asked: *Have you heard about scientific terms such as facts, concepts, principles, laws and theories before? In your understanding, what are they or what do they mean?*

When she was asked about these, she looked hesitant to answer and tried to explain her ideas with low confidence. Her answer was:

... To give definitions ... based on my understanding? A law should be, what should it be? Explaining from Thai language, law in Thai language is a regulation, an agreement, right? Being regulation, rule, standard, order ... which we have created ... Fact ... it should be different ... Law, sometimes we set it but we can not do [or follow] it, but the fact? Um... it [fact] should have been analyzed as being correct. [Fact] should pass analysis before ... as we told students to think of a classroom rule. Then, students told us but they may not be able to do. But, what they could have told should be a law or order ... Theory, I do not teach older students. There are not many theories

for [young students] to think or search ... I have never taught older students in this subject. So, I rarely explain about theories. It is quite hard for me to explain about what theory is ... I have to tell, 'wait and let me search out first' similar to students searching about them ... I need time to search. I can not remember everything (Ms. Dara).

This interview response shows that Ms. Dara tried to explain the definition of scientific laws based on her perspective of a Thai language teacher. She thought that laws were something which had been set by people as regulation or agreement to follow. About scientific facts, she thought that scientific facts should come after analysis. In another words, scientific facts should have been verified. It seems that Ms. Dara could not give any ideas about scientific theories and she gave the reasons as being because she taught at lower primary school level and there were not many scientific theories for students to learn.

After attending the program, Ms. Dara's responses to statements about different kinds of scientific knowledge on the NOSI questionnaire are shown in items 7 and 8 of Table 5.2. Ms. Dara still strongly disagreed with item 7. This could mean that she had a correct understanding about the difference between using the words facts, concepts, principles, laws and theories in science and in daily life. That Ms. Dara still strongly agreed with item 8 suggested she had the misconception that scientific facts could be simply developed to become scientific theories which then turn into scientific laws.

iii) Specific Characteristics of Scientific Knowledge

Before attending the program, Ms. Dara's responses to statements about specific characteristics of scientific knowledge on the NOSI questionnaire are shown in items 9 to 11 of the Table 5.2. Ms. Dara disagreed with item 9 and strongly disagreed with items 10 and 11. This implies that Ms. Dara had contemporary views on the aspect which recognized that scientific knowledge is tentative, questionable, empirical-based, and subjective.

In the semi-structured interview, Ms. Dara was asked: *How could you distinguish which knowledge is scientific knowledge? Or how could you know what is scientific knowledge?* When Ms. Dara was asked about these, she took time to think before she expressed her ideas. She gave her brief answer:

... It [Scientific knowledge] should be higher order thinking. Analysis, analysis thinking is probably science... Scientific knowledge should have thinking, analytical thinking, [and] reasoning. It should have rational thinking (Ms. Dara).

Thus, an interview response showed that Ms. Dara seemed to emphasize that scientific knowledge was different from other kinds of knowledge because it has higher order thinking, analytical thinking, and rational thinking.

In the fifth session of the program, there was a discussion to summarize conceptions of the Nature of Science gained from doing experiments and reading articles. Ms. Dara mentioned that scientific knowledge was changeable.

After attending the program, Ms. Dara still strongly disagreed with item 9 and strongly agreed with item 11 of the NOSI questionnaire. From this it could be inferred that Ms. Dara had a contemporary view which recognized that scientific knowledge is tentative, questionable, and empirically based. For item 10, Ms. Dara changed to agreeing with this item. So it could be inferred that Ms. Dara had a traditional view which lacks understanding of the subjective characteristics of scientific knowledge.

1.2.3 Development of Scientific Knowledge

(1) Scientific World View and Basic Assumptions of the Nature of Science

Before attending the program, Ms. Dara's responses to statements about the scientific world view and the basic assumptions of the Nature of Science on the NOSI questionnaire are shown in items 12 to 16 of Table 5.2. Ms. Dara strongly agreed with item 12. This could mean that she had a contemporary view that the world could be understood by human intellect and the construction of reasonable explanations. Ms. Dara made a neutral choice to item 13. From this it could be inferred that she might have mixed views between traditional and contemporary. She might neither agree nor disagree with the traditional view that the world and universe occurred in consistent patterns and that we could discover these patterns. Ms. Dara's responses to items 14 and 16 clearly show that she had traditional view which emphasized that science could provide absolute certainty or discover the truth of the natural world with lack of concern for its inherent limitations. From Ms. Dara's response to item 15 as 'do not understand', it could be inferred that she might not have known about the limitations of scientific inquiry before.

After attending the program, Ms. Dara still strongly agreed with item 12. This could mean that she had a contemporary view that the world could be understood by human intellect and its construction had a reasonable explanation. Ms. Dara more strongly agreed with item 13. This could imply that she had a traditional view that the world and universe occurred in consistent patterns which we can discover. Ms. Dara's response to item 14 showed that she still had traditional views which emphasized that science could provide absolute certainty or discover the truth of the natural world. Ms. Dara changed to strongly agree for item 15 and still agreed with item 16. From this it could be inferred that she had a contemporary view concerning the inherent limitations of science and the limitations of scientific inquiry.

(2) Scientific Method and Process

Before attending the program, Ms. Dara's responses to statements about scientific method and process on the NOSI questionnaire are shown in items 17 and 18 of Table 5.2. Ms. Dara strongly disagreed with item 17. This means that she had a contemporary view which emphasized that scientific method and process is theory-laden. Her response to item 18 showed that she strongly agreed with the traditional view which emphasizes that scientific experiment or scientific method are the means to generate and verify truth in scientific knowledge as true or false.

In the semi-structured interview, Ms. Dara was asked: *Do scientists have any processes? What are their processes?* Her answer was:

It would be process about where it came from, how it came. It has steps from everyday observation to see how it started, developed, and changed. It would be process. [Scientists] may not know [every concept] all at once ... Yes, [scientists] have their process of thought (Ms. Dara).

The answer showed that Ms. Dara thought that scientific process started from observation which cooperated with the thinking process to describe or explain the processes and development of observed phenomenon.

In the second session of the training program, there was a reading of the 'Inquiry Story' and articles of recent scientists' work. It was found that Ms. Dara could summarize and present major components of scientific process including observing; hypothesizing; searching for evidence by interview, investigation, and data gathering; doing experiments; and drawing conclusions.

While participating in the program, Ms. Dara seemed to be interested in the discussion about some scientific process skills after reading the 'Inquiry Story' and articles of recent scientists' work and after doing scientific

experiments dealing with free falling objects. In the second session, Ms. Dara discussed the meaning of the word 'hypotheses'. Then, in the fifth session, she asked the facilitator to describe and give her examples of characteristics of good hypotheses. In the fourth session, Ms. Dara participated in discussion about scientific process skills and the concepts of the Nature of Science after doing the experiment. She mentioned the various ways to present scientific results including describing, demonstrating, and using tables. From doing the experiment, she seemed to realize the importance of keeping data records. She found that if she forgot to record the data while doing the experiment, she could not remember the results for presentation of the findings. She also noted that she did not understand about scientific questioning and she felt that it was difficult to set the questions for guiding the experiment or for discussion of the data.

In the interview after the program Ms. Dara recognized the role of prediction in scientific inquiry. She said:

... Before the training, I used to think only that science must be true ... it is truth ... it does not relate to magic ... science must be provable ... I did not think about prediction ... when considering the Nature of Science, I found it was much more than what I have thought ... there was scientific process, I knew, I would apply science to my teaching ... by letting students raise the questions and make prediction of phenomena about what will happen next (Ms. Dara).

After attending the program, Ms. Dara still strongly disagreed with item 17 of NOSI questionnaire. This means that she had a contemporary view which emphasizes that scientific method and process is theory-laden. Her response to item 18 showed that she still strongly agreed with the traditional view which emphasizes that scientific experiments or scientific method are the means to generate and verify truth in scientific knowledge as true or false.

(3) Characteristics of Scientific Inquiry

Before attending the program, Ms. Dara's responses to statements about the characteristics of scientific inquiry on the NOSI questionnaire are shown in items 19 to 22 of Table 5.2. Ms. Dara's strong agreement with item 19 could mean that she had the traditional view that scientists use only a single scientific method, or other sets of orderly and logical steps, as tools for their research. Her response to item 20 showed that she had a contemporary view which emphasizes that science is an attempt to explain and predict phenomena as the most accurate reflection of reality having regard to its limitation to discovering or revealing the absolute truth. Ms. Dara chose the neutral response for item 21. This could mean that she had mixed traditional and contemporary views on the role of imagination and creativity in scientific inquiry. In another words, she might think that scientists either used or did not use imagination and creativity in their work. For item 22, Ms. Dara chose to respond 'do not understand' which could imply that she might not know that communication of scientific results contributes to scientific inquiry. It was found from the interview that she seemed not to know about the process of scientific experiment. As she described one of her teaching activities:

... I used to teach about rocks. I let students bring some rocks, let students classify rocks based on their characteristics, let them try to touch rocks and tell me about rocks' surfaces. I don't know whether it is experimentation or not but I used this activity. (Ms. Dara).

In the fifth session of the program, there was a discussion to summarize conceptions of the Nature of Science gained from doing experiments and reading articles. During this discussion, Ms. Dara recognized that the process of scientific experiment was a part of scientific inquiry.

After attending the program, Ms. Dara changed to strongly disagree for item 19 of NOSI questionnaire. This could mean that she had a contemporary view which recognized that scientists do not use only a single scientific

method, or fixed sets of orderly and logical steps, as tools for their research. Her response to item 20 showed that she still had the contemporary view that science is an attempt to explain and predict phenomena as the most accurate reflection of reality having regard to its limitation to discover or reveal the absolute truth. Ms. Dara more strongly disagreed with item 21. This could mean that she had contemporary view on the role of imagination and creativity in scientific inquiry. She may have thought that scientists used imagination and creativity in their work. For item 22, Ms. Dara still agreed with this item. From this it could be inferred that she had a contemporary view which recognized that communication of scientific results contributed to scientific inquiry.

1.2.4 Interrelation between Science, Technology, and Society

For this major aspect, Ms. Dara's understanding was investigated as a whole, and as particular points: interrelation between science and technology, and the interrelation between science and society.

Before attending the program, for the whole aspect of interrelation between science, technology, and society, Ms. Dara's responses to statements about these aspects in the NOSI questionnaire are shown in item 25 of Table 5.2. These showed that Ms. Dara strongly agreed with this item which means that she had a contemporary view in recognizing the interrelation between science, technology, and society.

In the semi-structured interview, Ms. Dara was asked: *What is the importance of science? How is it important to technology and society?* Her answer was:

... Science should relate mostly to our daily life because nowadays science is very important. If children do not have scientific knowledge, they would live in suffering. It is hard to live in society because now our lifestyle, environment, food, even clothing are interrelated with technology. From

when we wake up until we sleep, they all relate to science. It is about how to protect ourselves, care for ourselves, and what are important and the need of our lives. (Ms. Dara).

The interview responses showed that Ms. Dara recognized the importance of science in daily life. She knew that science is related to all aspects of living and is related to technology. She seemed to emphasize the use of scientific knowledge in protecting and caring for oneself.

After attending the program, Ms. Dara's responses to statements on the NOSI questionnaire showed that Ms. Dara still strongly agreed with this item which means that she had a contemporary view in recognizing the interrelation between science, technology, and society.

Ms. Dara's responses to the particular points of interrelations between science and technology, and between science and society in the questionnaire are shown and discussed below.

(1) Interrelation between Science and Technology

Before attending the program, Ms. Dara's response to a statement about the interrelation between science and technology on the NOSI questionnaire is shown in item 26 of Table 5.2. Ms. Dara chose to respond 'do not understand' to this item. This could imply that she might not know about the interrelation between science and technology.

During the sixth session of the program, there was a discussion about whether science or technology came first. Ms. Dara argued that science and technology were related but science should come before technology. This is because science led to technological development. The facilitator raised the issue that we have used facilities which were the products of technology such as fire or stone weapons, since before we had any understanding of and explanation for them. Ms. Dara

responded to this issue that we have used scientific processes such as doing experiments or trial and error until we found the products. Thus, it seemed that Ms. Dara firmly thought that science came before technology because she viewed science as a process to develop technological equipment.

After attending the program, Ms. Dara still strongly agreed with item 26 of NOSI questionnaire. From this it could be inferred that she had a contemporary view which recognized the interrelation between science and technology.

(2) Interrelation between Science and Society

Before attending the program, Ms. Dara's responses to statements about the interrelation between science and society on the NOSI questionnaire are shown in items 23, 24, and 27 to 29 of Table 5.2. Her responses to these items show clearly that Ms. Dara had a strong contemporary view of the interrelation between science and society. So it could be inferred that Ms. Dara viewed that science as not separated or in isolation from humanity as she strongly disagreed with items 24 and 28. She recognized the social and cultural context in which scientists work and social aspect of science in which science is a complex social activity, as she strongly agreed with item 23. She recognized the historical aspect of science or evolutionary and revolutionary characteristics of science as she strongly agreed with item 29. She appreciated that scientists could not work with value- and ethics-free attitudes as she strongly disagreed with item 27.

In the fifth session of the program, there was a discussion to summarize the conceptions of the Nature of Science gained from doing experiments and reading articles. It was found that Ms. Dara recognized that science related to society by helping to improve the quality of life.

After attending the program, Ms. Dara still had strong contemporary views of the interrelation between science and society as indicated in

all of her responses to items 23, 24, 27, 28 and 29 of NOSI questionnaire. These findings could imply that Ms. Dara viewed that science is not separated or in isolation from humanity as she strongly disagreed with items 24 and 28. She recognized the social and cultural context in which scientists work and the social aspect of science in which science is a complex social activity as she strongly agreed with item 23. She recognized the historical aspect of science or the evolutionary and revolutionary characteristics of science as she strongly agreed with item 29. She appreciated that scientists could not work with value- and ethics-free attitudes as she strongly disagreed with item 27.

1.2.5 Characteristics of Scientists and Scientific Attitudes

Before attending the program, in the semi-structured interview, Ms. Dara was asked: *What are the characteristics of scientists?* Her answer was:

Scientists? In my opinion, since I was young, I think scientists are clever people ... they are omniscient. They have knowledge much more than other people ... Being observant, thoughtful, researcher, inventor ...analyst ...everything is all in a scientist. (Ms. Dara).

From her answer, it could be seen that Ms. Dara seemed to view scientists as a group of people who are smarter than other people generally and to appreciate the curiosity and reasoning aspects of scientific attitudes.

In question number 4 of the open-ended part of the NOSI questionnaire, Ms. Dara was asked to express her understanding of the components of scientific attitudes. The question was: *What are the scientific attitudes or habits of mind that students should gain from learning science?*

Ms. Dara's answers did not relate to the question. Her written statements responding to this question were:

(1) Like to learn science, (2) Pay attention to learning, and (3) Know how to acquire knowledge.

From these responses it could be inferred that she might confuse the distinctions between attitudes toward science or science learning and scientific attitudes or habits of mind. It seemed that she failed to recognize the importance of scientific attitudes in science teaching and learning though she had already appreciated some of their components.

In the fifth session of the program, there was a discussion to summarize the conceptions of the Nature of Science gained from doing experiments and reading articles. It was found that Ms. Dara recognized that scientists must be suspicious.

1.3 Teacher's Understandings of Instructional Approaches of the Nature of Science

In this section, data from interviews, classroom observation, questionnaire responses and documents were gathered and analyzed to discover Ms. Dara's understanding of instructional approaches related to the Nature of Science before and after attending the program. The findings are presented in two sub-topics; objectives of science teaching, and teaching approaches.

1.3.1 Objectives of Science Teaching

Before attending the program, Ms. Dara stated in the questionnaire and interview responses that her objective in science teaching was to develop students' abilities in performing the process of knowledge inquiry by observing, exploring, investigating, and researching systematically. The important topics in her science teaching were living things and living processes. She emphasized developing students' skills in observation, classification, acquiring of knowledge, and application

of knowledge for self improvement in daily life. She mentioned that students should have a good attitude toward learning science.

In the first session of the program before starting training activities, in the open-ended part of the NOSI questionnaire, Ms. Dara was asked to write down her aims in science teaching and learning with reasons. She stated that her science teaching was to develop students' abilities in solving problems, thinking critically and rationally, and living with happiness. Students should be able to efficiently apply these to their daily life.

During the program, in the first session, Ms. Dara seemed to be impressed with the 'best practice' teacher's aim to develop students to be scientists. She joined in the discussion and seemed to agree with the idea of the majority of the class which thought that this aim was not suitable for science teaching and learning at the lower primary school level. In the seventh session, Ms. Dara joined in the discussion about the relationship between the aims of science teaching and a teacher's views on science. She seemed to recognize that the objectives of science teaching should be related to the teachers' view of science.

After the program, Ms. Dara was asked, if she wanted to, to review her answer to the open-ended part of the NOSI questionnaire and to rewrite her aims for science teaching and learning with reasons. Ms. Dara added more new aspects to her answers. She stated that students should recognize the relationship between science and technology as they affected each another. Students should have scientific attitudes, moral, ethical, and attitudes in using science and technology creatively. Students should have abilities in investigation, thinking, imagination, communication, and in making decisions.

1.3.2 Teaching approaches

Before attending the program, Ms. Dara considered that in order to learn about the processes and skills of science, students should learn to practice their

skills and learn about scientific process. She thought that if students are to learn to be like scientists, teachers should prepare well for their teaching. She thought that a teacher should teach from real things and real settings such as letting students do experimentation.

In Ms. Dara's science teaching, she used observation, classification and exploration of surrounding things and the school grounds, questioning and classroom discussion, presentation in front of the class, individual practical work, and group work. She also taught by integrating science with other subjects in some topics which had related or similar contents. The instructional media and resources she used in her teaching were pictures, students' worksheets, and some practical and simple things in the school grounds and surroundings.

To assess their learning of science, Ms. Dara used observation of students' performances while engaging in science class activities. She corrected students' work and had paper-pencil tests for her students after finishing the topics. These tests were mainly composed of matching pictures, drawing and painting the answers because her students still could not write the answers in long sentences. Sometimes, if some students could not write, she would ask them to answer the tests orally.

In the first session of the program, before the training activities, Ms. Dara was asked to write down her teaching approaches for the Nature of Science in the open-ended part of the NOSI questionnaire. Here she stated that science was life-long learning. Teachers should set teaching and learning continuously. Students should learn from direct experiences by doing systematic investigation and research by themselves.

During the program, in the fifth session, Ms. Dara shared her ideas and experiences about how to develop students' understanding of the Nature of Science. She mentioned that students could learn the Nature of Science from observation, doing experiments, exploration, and classification. When discussing how

she felt doing the inquiry activity in the previous session, she mentioned that it made her feel curious. She had given the article of 'Scientists' Experiments on Free Falling of Objects throughout History' to her students to read. She found that her students were curious and wanted to do experiments similar to what she did in the training program. Ms. Dara joined the discussion of students' learning of science and the characteristics of good science teaching in the seventh and eighth sessions. Ms. Dara thought that students should learn from real things. They should take part in observation, investigation or research by themselves as learning by doing for they would gain understanding which would become a long-term memory.

After the program, Ms. Dara was asked to review her answer on the open-ended part of the NOSI questionnaire and, if she wanted to, to rewrite her teaching approaches for the Nature of Science. She wrote new answers. Her teaching approaches for the Nature of Science were learning by interest, self-learning, participation in learning activities, doing self experiment, practicing rational thinking, practicing solving problems, collaborative learning, knowing how to use scientific process, and recognizing the importance of what students had learnt [reflecting on knowledge]. The scientific process from her answer was composed of observing, data recording, hypothesizing, experimenting, and concluding the results.

In the interview after the program Ms. Dara seemed to appreciate more about using scientific process in her science teaching, especially questioning, designing and planning for investigation and doing experimentation. She also appreciated more about using group work in the science class. She said:

I use more process. I know how to prepare worksheets ... to select which one can be used for students to record [data]. I use more group work. After the training, when I used group work process [students] could help one another. So, I will use it more ... From what you [facilitator] had taught, I know more about the science process, inquiry and investigation. I've never thought about what, why, and how. I've never thought I would question. Right now, I know about using questions with students, asking why and how. I improved one

more step. I know more about using questions with students...I let students do more investigation, more than before I attended the training (Ms. Dara)

Concerning the teaching approaches for the Nature of Science and how she thought about using reflective questions, Ms Dara was asked “*What did you do that was similar to scientists?*” Ms. Dara expressed her views by emphasizing the use of hands-on activities such as doing experiments and using science processes. She also used reflective questions with students. Ms. Dara said that:

In science students should really see and touch real objects and really do experiments ... We must emphasize [science process]. If not, students cannot work. They don't know how to do planning ... Why don't we use [reflective questions] with students the same as when we were in the training? ... Why don't we ask students similar to what [facilitator] asked teachers?... in the future, when we teach about this, we may apply this activity to students (Ms. Dara).

1.4 Teaching of the Nature of Science

From classroom observation, Ms. Dara's process of science teaching before and after attending the program could be summarized and illustrated in four sub-topics: classroom setting, introductory, teaching and learning activities, and conclusions.

1.4.1 Classroom setting

Before attending the program, Ms. Dara generally taught science in her classroom. She set students' desks in groups of four to five students. There were approximately 35 students in her class. The setting is illustrated in Figure 5.1 below.

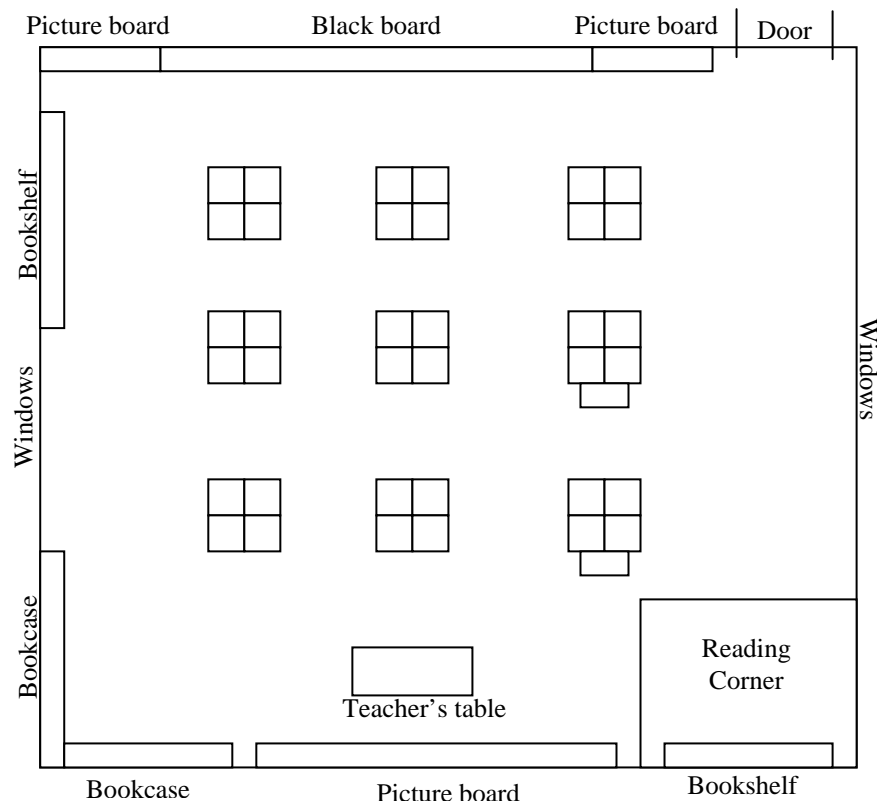


Figure 5.1 Ms. Dara's Classroom Setting Before the Program

On the walls and the boards around the classroom, there were posters of pictures and learning information on the topics of science, environment, food, health, animals, numeric characters, Thai alphabet characters, and students' work. There was a reading corner for students to spend their free time sitting on the floor and reading some interesting books.

In the 2005 academic year, after attending the program, Ms. Dara taught science in the same classroom as the 2004 academic year. She set students' desks in rows of two students. Ms. Dara used both her classroom and school grounds in teaching science. There were approximately 35 students in her class. The setting is illustrated in Figure 5.2 below.

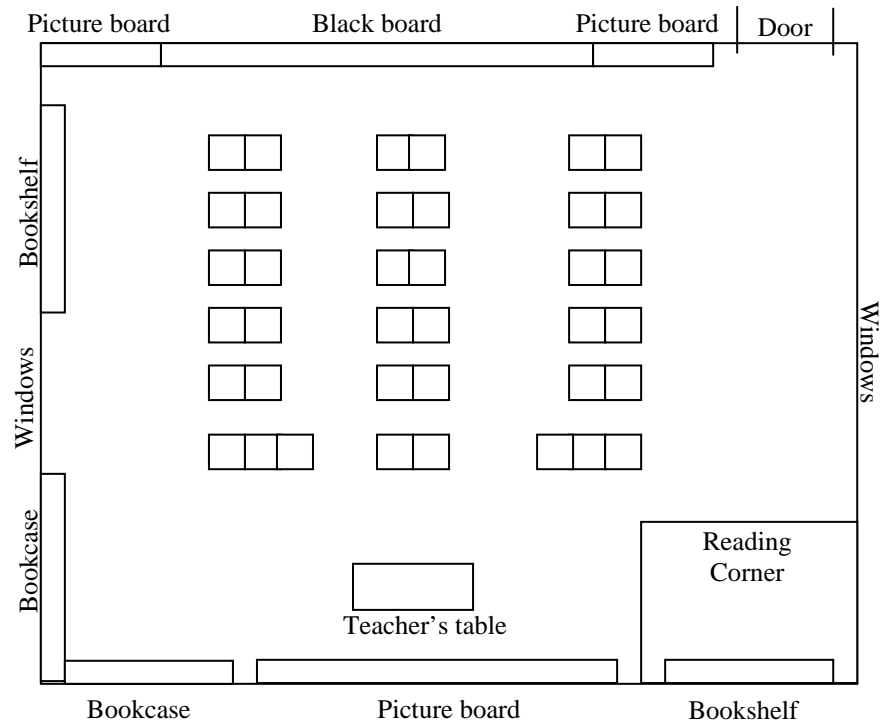


Figure 5.2 Ms. Dara's Classroom Setting After the Program

There were posters of pictures and information on the walls and the boards around the classroom and a reading corner for students to spend their free time sitting on the floor and reading some interesting books, similar to the setting in the 2004 academic year.

1.4.2 Introductory

Before attending the program, Ms. Dara started the lesson by motivating student interest in learning a topic. She mainly used classroom discussion with some learning media such as pictures. The discussion was focused on students' prior knowledge and experiences related to the learning topics. For example, she used pictures of a forest and a waterfall to discuss their experiences with the students.

After attending the program, Ms. Dara started the science class by setting students in groups, about five groups. Then, she informed students about an exploration in the school grounds. She gave students worksheets and asked them to read the instructions by themselves. After the students read these, she discussed how to do the activities following the instructions on the worksheet.

1.4.3 Teaching and learning activities

Before attending the program, Ms. Dara led students to discuss a learning topic and concept. She questioned students and had students answer. She used students' worksheets to help students gain an understanding of a learning topic and concept. By doing the worksheet, students also practiced some basic skills such as observation and classification. For example, Ms. Dara taught the concepts of living and non-living things. After classroom discussion to distinguish between living and non-living things, she gave worksheets to each group of students and asked them to find out living and non-living things from a picture in the worksheet. Ms. Dara also practiced students' communication skills. After group work, she had presenters from each group come out and present the findings of their group in front of the class.

After attending the program, Ms. Dara gave students time to do observations in groups. Each group of students was doing activities following the instructions. Ms. Dara walked around to give each group suggestions, discussion, and feedback. Using the topic of the atmosphere, students were studying the different heat of the air in shade and in sunlight. Each group of students stood under the tree in front of the building. They wrote in the work sheet, noting what they felt when standing in shade. Then, each group of students went to stand outside the building in the sunlight for a while. They came back to write in the worksheet describing what they felt when standing in sunlight. After that, students discussed in their groups the different feelings between standing in shade and in sunlight. Finally, students wrote the conclusion of the activity.

1.4.4 Conclusion

Before attending the program, Ms. Dara used classroom discussion to help students reach conclusions about the learning concepts. To ensure students' understanding of these concepts, she had students doing other worksheets individually before finishing the science class. For example, Ms. Dara discussed the topic with students and led students to conclude characteristics of living and non-living things. Then, she gave new worksheets to each student and asked them to find out living and non-living things by themselves and write their conclusions of characteristics of living and non-living things on the worksheet.

After attending the program, Ms. Dara brought her students back to the classroom after all the groups finished their exploration. She asked each group to send a student to present their findings in front of the classroom. Finally, Ms. Dara led students to conclude the scientific concepts gained from the activity.

1.5 Factors' Affecting Teacher's Teaching of the Nature of Science

In the interview before the program development and implementation, Ms. Dara expressed her perceptions of factors which affected her science teaching in three major topics: readiness of students and classroom control, school and parental support, and teacher's workload.

1.5.1 Readiness of students and classroom control

Ms. Dara considered that she had to be patient when teaching science with practical work such as observation or exploration. This was because students were young and disorderly when doing activities.

1.5.2 School and parental support

Ms. Dara mentioned that most parents gave good support to her science teaching by preparing learning materials for their children to bring to school. She considered that the support of parents in taking their children outside and letting

them gain direct experience could promote students' interest in learning science in the class and could support students in learning faster than students who had less direct experiences.

For school support, she thought that most science lessons had simple contents and used basic and inexpensive teaching and learning resources and media which she could prepare by herself. Thus, there was no need to ask for money support from the school.

1.5.3 Teacher's workload

Ms. Dara thought that in teaching science she needed time to prepare activities and worksheets. Sometimes, other responsibilities in school such as teacher meetings, extra work and school activities had affected her preparation for science teaching.

1.6 Perspectives on the Program

In the interview after completion of the program, Ms. Dara discussed perspectives on what she had learnt from attending the program, the advantages of the program, and the disadvantages of the program. These perspectives are shown under the three sub-topics discussed below.

1.6.1 What the teacher had learnt from attending the program

What Ms. Dara had learnt from the program could be divided into two major groups: conceptions of the Nature of Science, and teaching and learning approaches.

(1) Conceptions of the Nature of Science

Ms. Dara mentioned that before she attended the program, she thought only that science was truth. It did not relate to magic and it could be proved.

She did not think about prediction in science. After attending the program, she realized that the Nature of Science was more than she had thought. She used to think about some aspects but had already forgotten or overlooked them. She thought that she gained more knowledge from having the discussions and sharing ideas with other peers. She also had a willingness to study more about the process and nature of science, following the guide lines which she had received from the program.

(2) Teaching and learning approaches

Ms. Dara had learnt more about teaching and learning approaches from the program on various issues. These issues are listed below.

- Knowing more about how to prepare students' work sheets for recording scientific data
- Knowing more about how to use group work in a science class
- Recognizing the process of scientific inquiry and using more questions with students
- Appreciating that to ask students about how what they did was similar to scientists would help to develop a positive attitude toward science
- Allowing students to do more investigation and make decisions about choosing their own methods
- Applying scientific process such as questioning and prediction in teaching mathematics and Thai language

1.6.2 Advantages of the program

Ms. Dara expressed her opinion that she had fun when joining the activities and thinking similarly to scientists. She rarely had chances to attend a training course in small groups with practical activities. She mentioned she felt confident to share her ideas when participating in the training program when every member knew each other very well.

1.6.3 Disadvantages of the program

Ms. Dara mentioned that limitations of time caused limitations in doing activities. She suggested that the training program should be held in holiday time for a half day or whole day. This is so the activities could be run continuously.

2. Case 2: Ms. Naphar

2.1 Teacher's Background and Participation in the Training Program

Ms. Naphar (pseudonym), a Grade 1 classroom teacher, graduated from a faculty of Education, majoring in teaching Thai language. She had about five years experience in teaching science integrated in the Life Experience group of subjects. Ms. Naphar had to teach science as an individual core subject for the first time in the 2004 academic year. She also had to teach almost eight core subjects. From the questionnaire, her responses were that she felt neutral about and did not like to teach science because she had not majored in science and lacked expertise in teaching it.

In the 2005 academic year, Ms. Naphar was a Grade 1 classroom teacher and taught in the same classroom as in the 2004 academic year. She taught all subjects including science, which she taught two periods per week. Ms. Naphar attended the program from the beginning but, she missed the sixth session and the last four sessions of the training program. She seemed to be quiet and a slow learner. She usually took a longer time than other teachers in writing and finishing activities. She usually took part in the discussion as a listener, but would share her ideas or answer the questions when the facilitator asked her directly. When working in groups or in pairs, she usually worked Ms. Dara.

2.2 Teacher's Understandings of Conceptions of the Nature of Science

From the statistical analysis of the whole rating scale part of NOSI questionnaire, Ms. Napar's mean score of all question items before and after attending the training program are summarized and shown in Table 5.3 below.

Table 5.3 Ms. Napar's Mean Score of all Question Items Before and After Attending the Program

Academic Year	Period	Mean Score
2004	Before the Program	3.250
2005	At the first session of the Program	3.231
	After the Program	3.462

From the table, it could be inferred that, on the whole, before attending the training program Ms. Napar had both traditional and contemporary views on the concepts of the Nature of Science. After attending the program, she still had both traditional and contemporary views on the concepts of the Nature of Science but her view appeared to be more contemporary.

Ms. Napar's responses to 29 rating scale items of the Nature of Science statements before and after attending the program are shown in Table 5.4 below. 'X' refers to the position of her agreement on the rating scale before and after attending the program. It also refers to her point of view on each statement in the range of traditional to contemporary view or in the range of misconception to right conceptions. 'O' refers to the position of her agreement on the rating scale in the first training session. If her agreement at both the first training session and after the program are in the same position, the symbol, '⊗' is presented.

Table 5.4 Ms. Napar's Responses to the Nature of Science Statements Before and After Attending the Program

Statements		Strongly agree	agree	Neutral	disagree	Strongly disagree
1	Science is only a body of knowledge which explains concrete things, natural phenomena, and the world around us.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				
2	Science is a process of exploring the unknown and discovering new things about our world and universe and how they work.	Contemporary <i>Before</i>			Traditional	
		←-----X-----→				
		At 1 st Period & After				
		←X-----O-----→				
3	Science is inventing and designing things and finding out ways to make people's lives better.	Misconception Naïve		Right		
		←-----X-----→				
		At 1 st Period & After				
		←-----X-----O-----→				
4	Scientific knowledge is discovered by scientists who make observations of the world and carefully record and organize the facts or truths in a systematic way.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				
5	Scientific knowledge is generated by scientists who attempt to explain and predict the natural phenomena based on empirical evidence and logical reasoning.	Contemporary <i>Before</i>		Traditional		
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				
6	We can trust in scientific knowledge because it is confirmed by scientific method, scientific experiments and approved by scientific community.	Contemporary <i>Before</i>		Traditional		
		←-----X-----→				
		At 1 st Period & After				
		←X-----O-----→				
7	The words facts, concepts, principles, laws and theories in science have the same meaning when being used in our daily lives.	Misconception Naïve		Right		
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				
8	Scientific facts come from observation and experiments, and then, always become scientific theories that, in turn, become laws.	Misconception Naïve		Right		
		←-----X-----→				
		At 1 st Period & After				
		←X-----O-----→				
9	We can not have questions about scientific theories and laws. They are 100% true according to reality and unchangeable. We have to remember and use them.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				
10	When scientists make arguments, their personal bias does not have an influence.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		At 1 st Period & After				
		←-----⊗-----→				

Table 5.4 (Continued)

	Statements	Strongly agree	agree	Neutral	disagree	Strongly disagree
11	Scientific knowledge can change if there is more evidence.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←X-----O-----→				
12	We make sense of the world by careful and systematic study for making reasonable explanations of phenomena.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
13	The world and universe occur in consistent patterns, we can discover these patterns by using the intellect and the aid of instruments.	Traditional			Contemporary	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
14	Science is the most powerful way of understanding and discovering the truth of the natural world.	Traditional			Contemporary	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←X-----O-----→				
15	Some matters cannot be examined usefully in a scientific way.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
16	Science can not completely explain the world and how it works, but, it can give accurate approximations.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
17	Scientists have no ideas about results before doing observations or experiments.	Traditional			Contemporary	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
18	Scientists do experiments to confirm scientific knowledge as proving the truth or falsehood of this knowledge.	Traditional			Contemporary	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←X-----O-----→				
19	Every scientist always does scientific investigations in the same way, as a fixed set of steps, to gain their scientific knowledge.	Traditional			Contemporary	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
20	Scientists try to explain and predict phenomena as the most accurate to the reality, although they know that they can not discover the absolute truth.	Contemporary		Traditional		
		<i>Before</i>				
		←-----Don't understand-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				

Table 5.4 (Continued)

Statements		Strongly agree	agree	Neutral	disagree	Strongly disagree
21	We can not use imagination and creativity to get scientific knowledge.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		<i>At 1st Period & After</i>		←-----⊗-----→		
22	Scientists need to communicate their scientific results and require peer review.	Contemporary <i>Before</i>			Traditional	
		←-----X-----→				
		<i>At 1st Period & After</i>			←-----X-----→	
23	Scientists always work individually in the laboratory, and social affairs outside do not affect their work.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		<i>At 1st Period & After</i>		←-----X-----O-----→		
24	Scientists are people like every bodyelse and participate in community both as specialists and as citizens.	Contemporary <i>Before</i>			Traditional	
		←-----X-----→				
		<i>At 1st Period & After</i>			←-----⊗-----→	
25	Science and technology affects society on the one hand, society affects science and technology on the other hand.	Contemporary <i>Before</i>			Traditional	
		←-----X-----→				
		<i>At 1st Period & After</i>			←X-----O-----→	
26	Technology gets ideas from science and science gets new processes and instruments from technology.	Contemporary <i>Before</i>			Traditional	
		←-----X-----→				
		<i>At 1st Period & After</i>			←X-----O-----→	
27	Scientists can do scientific research by do not have to give much consideration to ethical principles.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		<i>At 1st Period & After</i>		←-----⊗-----→		
28	Science is only scientists' work. Other groups of people in society can not participate.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		<i>At 1st Period & After</i>		←-----⊗-----→		
29	Todays' scientists develop scientific knowledge from previous knowledge according to history.	Contemporary <i>Before</i>			Traditional	
		←-----Don't understand-----→				
		<i>At 1st Period & After</i>			←-----X-----O-----→	

Ms. Napar's conceptions of the Nature of Science before, during and after attending the program are described in detail within five major aspects of the Nature of Science.

2.2.1 Definitions of Science

Before attending the program, as shown in Table 5.4, Ms. Napar responded to items 1 and 2 of the NOSI questionnaire by choosing neutral to traditional and contemporary views of the definitions of science. From this it could be inferred that she had a mixed or a blended view of the definition of science. She seemed to view science as both a body of knowledge and a process for understanding the world.

In the open-ended part of the questionnaire Ms. Napar identified the subject of science as being related to scientific process and process skills, analytical thinking and reasoning, problem-solving processes, and application of knowledge to daily life. It could be inferred that she would adopt a contemporary view of science as a process into her classroom teaching.

For item 3, she also chose neutral to the statement that science is inventing and designing things and finding ways to make people's lives better. This implies that Ms. Napar had a naïve view of the differences between science and technology. She seemed to view science in terms of technology and she might have a utilitarian view, thinking that the aim of science is to help finding ways to make people's lives better.

In the first session of the program, there was a discussion about teacher's personal views on science and teaching science. Ms. Napar expressed her personal idea that science was systematic problem-solving which could be used in daily life. Thus, she seemed to view science as a process.

After attending the program, Ms. Napar responded to items 1 and 2 of the NOSI questionnaire with 'disagree' in item 1 and more strongly agree with item 2. From this it could be inferred that she had contemporary view of the definition of science. She seemed to view science as a process to understand the world.

For item 3, she agreed more with the statement which stated that science is inventing and designing things and finding out ways to make people's lives better. From this it could be inferred that Ms. Napar had an alternative conception of the differences between science and technology. She seemed to view science in terms of technology and she might have utilitarian views which regard the aim of science as to help find ways to make people's lives better.

2.2.2 Scientific Knowledge

(1) Source of Scientific Knowledge

Before attending the program, Ms. Napar responded to questionnaire items 4 and 5 by choosing neutral to the traditional view of the source of scientific knowledge that scientific knowledge was discovered by scientists through observation and scientific method. She agreed with the contemporary view of the source of scientific knowledge that scientific knowledge was generated by scientists through their process of thought, based on empirical evidence. Thus, it could be inferred that Ms. Napar seemed to have more of a contemporary view of the source of scientific knowledge than a traditional view on this subject.

After attending the program, Ms. Napar's responses to questionnaire items 4 and 5 still agree with the traditional view of the source of scientific knowledge that scientific knowledge is discovered by scientists through observation and scientific methods. She also still agreed with the contemporary view of the source of scientific knowledge that it is generated by scientists through their process of thought based on empirical evidence. Thus, Ms. Napar seemed to view scientific knowledge as coming from both discovery and generation by scientists.

(2) Nature of Scientific Knowledge

There are three sub-points of the nature of scientific knowledge focused on in this research: validity of scientific knowledge, definition of different kinds of scientific knowledge, and the development of scientific knowledge.

i) Validity of Scientific Knowledge

Before attending the program, Ms. Napar's response to a statement about the validity of scientific knowledge on the NOSI questionnaire is shown in item 6. She agreed with the contemporary view which emphasized that validity of scientific knowledge was based on both confirmation of empirical evidence through scientific method and experiments and approval of scientific community.

After attending the program, it was found that she agreed more strongly with the contemporary view which emphasized that the validity of scientific knowledge is based on both confirmation of empirical evidence through scientific method and experiment and the approval of the scientific community.

ii) Definitions of Different Kinds of Scientific Knowledge

Before attending the program, Ms. Napar's responses to statements about different kinds of scientific knowledge on the NOSI questionnaire are shown in items 7 and 8. Table 5.4 shows that Ms. Napar made the neutral choice to item 7. This could mean that she had a naïve understanding about the difference between using the words facts, concepts, principles, laws and theories in science and using these words in daily life. Ms. Napar agreed with item 8 which could infer that she had an alternative conception that scientific facts could be simply developed to become scientific theories which then turn into scientific laws.

After attending the program, Ms. Napar still made the neutral choice to item 7. This could mean that she had a naïve understanding about the

difference between using the words facts, concepts, principles, laws and theories in science and using these words in daily life. From Ms. Napar's more strongly agreeing to item 8 it could be inferred that she held the misconceptions that scientific facts could be simply developed to become scientific theories which then turn into scientific laws.

iii) Specific Characteristics of Scientific Knowledge

Before attending the program, Ms. Napar's responses to statements about specific characteristics of scientific knowledge on the NOSI questionnaire are shown in items 9 to 11. Ms. Napar disagreed with item 9 but agreed with items 10 and 11. From these it could be inferred that Ms. Napar had a contemporary view on the aspect which recognized that scientific knowledge is tentative and changeable. She had a traditional view which lacked concern for the subjective and perceptually bonded characteristics of scientific knowledge.

After attending the program, Ms. Napar still disagreed with item 9 and agreed more strongly with item 11. From this it could be inferred that she had a contemporary view which recognized that scientific knowledge is tentative, changeable, and empirically based. In the interview after the program, Ms. Napar stated that "science was not static". Ms. Napar still agreed with item 10. From this it could be inferred that she had a traditional view which lacked concern for the subjective and perceptually bonded characteristics of scientific knowledge.

2.2.3 Development of Scientific Knowledge

(1) Scientific World View and Basic Assumptions of the Nature of Science

Before attending the program, Ms. Napar's responses to statements about a scientific world view and the basic assumptions of the Nature of Science on the NOSI questionnaire are shown in items 12 to 16. As shown in Table

5.4, Ms. Napar made the neutral choice to all of these items. This suggests that her view was in between traditional and contemporary views on all sub-aspects of scientific worldview and basic assumptions of the Nature of Science. For item 12, she neither agreed nor disagreed with contemporary view that the world could be understood by human intellect and the construction of a reasonable explanation. For item 13, she neither agreed nor disagreed with the traditional view that the world and universe occurred in consistent patterns which we could discover. Ms. Napar's responses to items 14, 15, and 16 showed that she neither agreed nor disagreed with the traditional view which emphasizes that science could provide absolute certainty or discover the truth of the natural world and contemporary view which believes that science and scientific inquiry have inherent limitations.

After attending the program, Ms. Napar still agreed with item 12. From this it could be inferred that she agreed with the contemporary view that the world could be understood by human intellect and that its construction has a reasonable explanation. For item 13, she still disagreed with the traditional view that the world and universe occur in consistent patterns which we could discover. Ms. Napar's responses to items 14, 15, and 16 showed that she seemed to have a more traditional view which emphasizes that science could provide absolute certainty or discover the truth about the natural world but is lacking concern about the inherent limitations of science and scientific inquiry.

(2) Scientific Method and Process

Before attending the program, Ms. Napar's responses to statements about scientific method and process on the NOSI questionnaire are shown in items 17 and 18 of Table 5.4. Ms. Napar disagreed with item 17. This means that she had contemporary view which emphasized that scientific method and process was theory-laden. She chose neutral to item 18. From this it could be inferred that she neither agreed nor disagreed with the traditional view which emphasizes that scientific experiments or scientific method are the means to generate and verify truth in scientific knowledge as true or false.

While participating in the program, Ms. Napar seemed to develop her understanding of some aspects of scientific process and scientific process skills. In the second session, after reading the 'Inquiry Story' and articles of recent scientists' work, she mentioned that she had learned more about scientific experiment. During the discussion in the third session on experiment design for free falling objects, Ms. Napar discussed the control of the environment for setting controlled variables and mentioned repeating experiments. After the activities, she stated in her journal writing that she had learnt about doing experiments for testing hypotheses or supporting ideas. She also learnt from doing experiments that the prediction of some things by common sense may not be as accurate as we had thought. The results depended on many variables which could cause error. In the interview after the program, she said that she learnt how to set hypotheses.

After attending the program, it was found that Ms. Napar still disagreed with item 17 of NOSI questionnaire. This means that she had contemporary views which emphasized that scientific method and process is theory-laden. She agreed more strongly with item 18. From this it could be inferred that she agreed with the traditional view which emphasizes that scientific experiments or scientific method are the means to generate and verify truth in scientific knowledge as true or false.

(3) Characteristics of Scientific Inquiry

Before attending the program, Ms. Napar's responses to statements about the characteristics of scientific inquiry on the NOSI questionnaire are shown in items 19 to 22 of the Table 5.4. Ms. Napar's disagreement with item 19 could mean that she agreed with the contemporary view which says that scientists do not use only a single scientific method, or fixed sets of orderly and logical steps, as tools for their research. For item 20, Ms. Napar responded 'do not understand' which suggests that she might not know that science was an attempt to explain and predict phenomena as the most accurate reflection of reality while still being concerned with its limitations in discovering or revealing the absolute truth. Ms. Napar disagreed with item 21, which could mean that she agreed with the contemporary view on the role of

imagination and creativity in scientific inquiry. For item 22, Ms. Napar chose neutral. From this it could be inferred that she neither agreed nor disagreed with the contemporary view which emphasizes the role of scientific results in contributing to scientific inquiry. In the open-ended part of the questionnaire, Ms. Napar mentioned some processes and skills relating to scientific inquiry including researching, problem-solving, and reasoning.

In the fifth session of the program, there was a discussion summarizing conceptions of the Nature of Science gained from doing experiments and reading articles. Ms. Napar recognized that observation and the process of scientific experiment is a part of scientific inquiry.

In the seventh session of the program, there was discussion of the teacher's view of science relating to their aims of science teaching. Ms. Napar mentioned the role of systematic, critical, and rational thinking in science. After the program, she also responded in the interview that science was a subject with reasoning. She thought that science depended on proving and reasoning.

After attending the program, Ms. Napar still agreed with item 19 of NOSI questionnaire. This could mean that she agreed with the traditional view which emphasized that scientists used only a single scientific method, or fixed sets of orderly and logical steps, as tools for their research. For item 20, Ms. Napar still disagreed. From this it could be inferred that she had traditional views which lacked a concern that science was an attempt to explain and predict phenomena as the most accurate reflection of reality while still being concerned with its limitation to discover or reveal the absolute truth. Ms. Napar still disagreed with item 21. This could mean that she agreed with the contemporary view on the role of imagination and creativity in scientific inquiry. For item 22, Ms. Napar changed from 'do not understand' to 'agree with' this item. From this it could be inferred that she agreed with the contemporary view which emphasizes the role of scientific results communication in contributing to scientific inquiry.

2.2.4 Interrelation between Science, Technology, and Society

For this major aspect, Ms. Napar's understanding was investigated as a whole and as the particular points, interrelation between science and technology, and interrelation between science and society.

For the whole aspect of interrelation between science, technology, and society, before attending the program, Ms. Napar disagreed with item 25 of the Table 5.4. From this it could be inferred that she agreed with the traditional view which had a lack of concern for the interrelation between science, technology, and society.

After attending the program, Ms. Napar more strongly agreed with item 25. From this it could be inferred that she agreed with the contemporary view which recognized the interrelation between science, technology, and society.

For particular points, Ms. Napar's responses to the questionnaire are shown and discussed in two sub-topics interrelation between science and technology, and interrelation between science and society.

(1) Interrelation between Science and Technology

Before attending the program, Ms. Napar chose the neutral response to a statement about the interrelation between science and technology on the NOSI questionnaire (item 26 of Table 5.4). From this it could be inferred that she neither agreed nor disagreed with the contemporary view of the relationship between science and technology.

After attending the program, Ms. Napar agreed more strongly with a statement about the interrelation between science and technology on the NOSI questionnaire in item 26. From this it could be inferred that she agreed with the contemporary view of the relationship between science and technology.

(2) Interrelation between Science and Society

Before attending the program, Ms. Napar's responses to statements about the interrelation between science and society on the NOSI questionnaire are shown in items 23, 24, and 27 to 29 of Table 5.4. Ms. Napar chose the neutral response to item 23. From this it could be inferred that she neither agreed nor disagreed with the traditional view which considers that scientific enterprise is isolated from society and does not recognize that science is a complex social activity. Ms. Napha's response as 'disagreed' in item 24 showed that she had a traditional view which considers that scientists are separated from humanity and society and does not regard science as part of intellectual, social, and cultural traditions. From Ms. Napar's disagreement with items 27 and 28 it could be inferred that she had a contemporary view that scientists could not work free from ethical considerations and that people from all cultures contribute to science. For item 29, Ms. Napar responded, 'do not understand'. From this it could be inferred that she might not know about the historical aspects of science or the evolutionary and revolutionary characteristics of science.

After attending the program, Ms. Napar agreed more with item 23. From this it could be inferred that she agreed with the traditional view which considers that scientific enterprise is isolated from society and does not recognize that science is a social complex activity. Ms. Napha's response as still disagreeing with item 24 showing that she had a contemporary view which considering that scientists are not separated from humanity and society and recognizing that science is part of intellectual, social, and cultural traditions. Ms. Napar still disagreed with items 27 and 28. From this it could be inferred that she had the contemporary view that scientists could not work free of ethical considerations and that people from all cultures contribute to science. Ms. Napar agreed more with item 29. From this it could be inferred that she agreed with the contemporary view which recognized historical aspects of science or the evolutionary and revolutionary characteristics of science.

2.2.5 Characteristics of Scientists and Scientific Attitudes

In the open-ended part of the questionnaire, before attending the program, Ms. Napar could not give an answer relating to the question about scientific attitudes (question number 4). She did not seem to know the meaning of scientific attitudes or habits of mind. However, from her responses to other open-ended questions, it was found that she emphasized the development of students' rational thinking. This rational thinking could be regarded as part of scientific attitude in the aspect of reasoning.

During the program, after reading the 'Inquiry Story' and articles of recent scientists' work, Ms. Napar stated that scientists were observant. Following the discussion summarizing conceptions of the Nature of Science gained from doing experiment and reading articles in the fifth session, Ms. Napar stated that scientists could accept change.

After attending the program, from the interview, Ms. Napar thought that the characteristics of scientists were observation, inventiveness, and liking for investigation. Thus, Ms. Napar seemed to develop an understanding of the curiosity and the broad-mindedness of scientists from her participation in the program.

2.3 Teacher's Understandings of Instructional Approaches of the Nature of Science

In this section, data from interviewing, classroom observation, questionnaire responses and documentary were gathered and analyzed to identify Ms. Napar's understanding of instructional approaches related to the Nature of Science before and after attending the program. The findings are presented in two sub-topics; objectives of science teaching, and teaching approaches.

2.3.1 Objectives of science teaching

Before attending the program, Ms. Napar stated in questionnaire responses that for her, the objective of science teaching was to develop students' abilities in critical thinking, in performing scientific process and skills, in solving problems systematically, and in the application of knowledge to daily life. The important topics in her science teaching were science, technology and environment. She emphasized developing students' skills in rational thinking, researching, and problem-solving. She mentioned that students should recognize the relationship between science, technology and environment.

In the first session of the program, before starting training activities, Ms. Napar was asked to write down her aims of science teaching and learning with reasons for these in the open-ended part of the NOSI questionnaire. She stated that her science teaching was to develop students' self understanding and develop students' ability to use reasoning and systematic investigation. This is because science is a systematic study and the learner must study processes and use reasoning.

During the program, in the first session, Ms. Napar, similarly to Ms. Dara, seemed to be impressed with the 'best practice' teacher's aim to develop students to be scientists. She joined in the discussion and seemed to agree with the majority of the class which thought that this aim was not suitable for science teaching and learning in lower primary school level. In the seventh session, Ms. Napar joined in the discussion about the relationship between the aims of science teaching and a teacher's views on science. She seemed to recognize the relationship between them, as she mentioned that students should learn by doing experimentation because science is related to critical, rational, and systematic thinking.

After the program, Ms. Napar was asked, if she wanted to, to review her answers in the open-ended part of the NOSI questionnaire and she was asked to rewrite her aims of science teaching and learning with reasons. Ms. Napar

added new aspects in her answers. She stated that students should be observant and know how to use processes in searching for data.

2.3.2 Teaching approaches

Before attending the program, Ms. Napar considered that science teaching and learning activities should be set based on subject content because different activities would be suited to different content. She thought that students should learn from various teaching and learning activities and learn from things in the surroundings by observation, comparison, and note taking and reasoning. Students could learn by self study and by group work. She mentioned that she chose teaching approaches which were appropriate, with researching, critical thinking, and problem-solving for application in daily life.

In her science teaching, it was found that Ms. Napar used questioning and classroom discussion as her major approaches. She used singing songs, playing games, and drawing pictures to assist her science teaching in order for students to learn about scientific facts and concepts. She also taught by integrating science with other subjects in some topics which had related or similar content. As instructional media and resources in her teaching she used pictures, drawing paper and crayon, the other students and some practical and simple things in the school grounds.

To assess students' learning of science, Ms. Napar used questioning, observation of performances during engagement in science class activities, correcting students' work, and paper-pencil tests after finishing the topics.

In the first session of the program, before starting training activities, Ms. Napar was asked to write down her teaching approaches for the Nature of Science in the open-ended part of the NOSI questionnaire. It was found that she stated that the teaching approaches for science were the study of things surrounding us by observation, comparison, data recording, and reasoning.

During the program, Ms. Napar did not express any ideas when there was discussion about how to develop students' understanding of the Nature of Science in the fifth session or how she had felt about doing inquiry activities in the previous session. She joined the discussion of students' learning of science and characteristics of good science teaching in the seventh and eighth sessions. She stated that students should be learning by doing science systematically because they like it. Students should learn by self study. Teachers should not provide information for them, but let them learn by themselves. Students should also learn from real things and learn things based on their interests.

After the program, Ms. Napar was asked to review her answer on the open-ended part of the NOSI questionnaire and she was asked, if she wanted to, to rewrite her teaching approaches for the Nature of Science. Ms. Napar did not change or add any new ideas. From the interview after the program, it was found that Ms. Napar thought that teaching the Nature of Science should start from a simple step such as observation. Then, teachers could move forward to hypothesis setting and investigation for orderly data. She also mentioned that teachers could use some techniques for guiding students in doing observation. We asked Ms. Napar about how she thought about using reflective questions, similar the way that scientists do. Ms. Napar seemed to appreciate the importance of indicating scientists' biography and their work in science teaching, saying:

If students know about who scientists are, how each scientist is important, what they invented, if we show them these, it would be good. This is because many scientists invented many things which we are using today. These relate to students and I think they should see this importance (Ms. Napar).

2.4 Teaching of the Nature of Science

From classroom observation, Ms. Napar's process of science teaching before and after attending the program is summarized and illustrated in four sub-

topics: classroom setting, introductory, teaching and learning activities and conclusions.

2.4.1 Classroom setting

Before attending the program, Ms. Napar generally taught science in her classroom. She set students' desks in rows of singles and pairs. There were approximately 33 students in her class. The setting is illustrated in Figure 5.3 below.

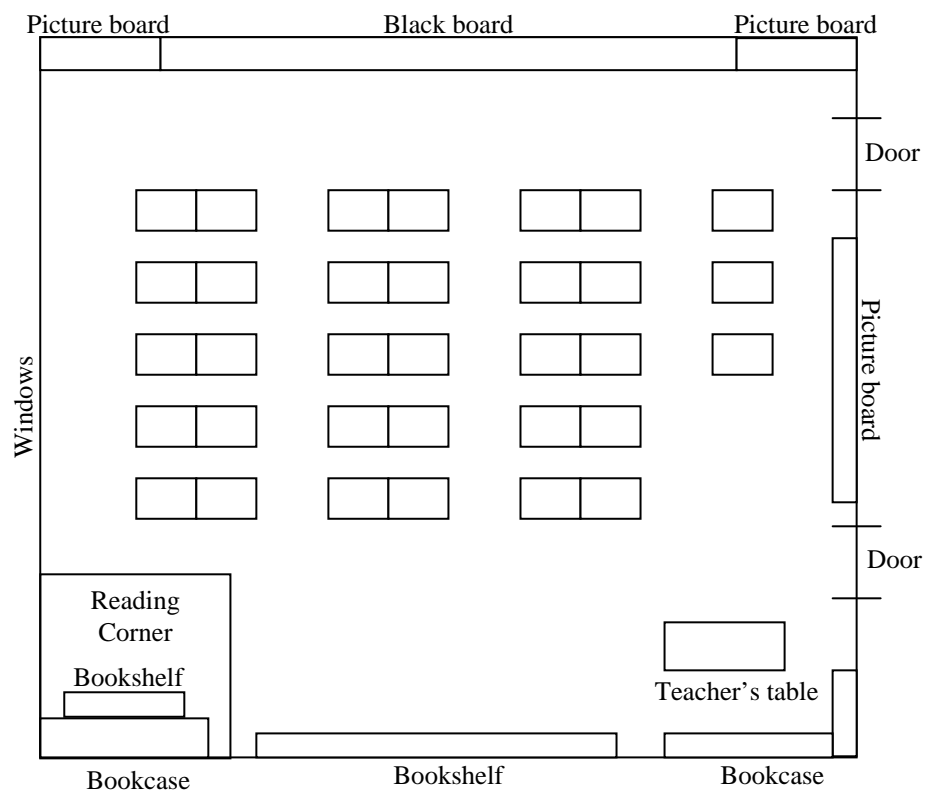


Figure 5.3 Ms. Napar's Classroom Setting Before the Program

On the walls and the boards around the classroom, there were posters of pictures and learning information on the topics of environment, food, health, numeric characters, Thai alphabetic characters, and students' work. There was a reading corner for students to spend their free time sitting on the floor and reading some interesting books.

In the 2005 academic year, after attending the program, Ms. Napar taught science in the same classroom of the 2004 academic year. Ms. Napar taught science in her classroom. She set students' desks in groups. There were approximately 34 students in her class. The setting is illustrated in Figure 5.4 below.

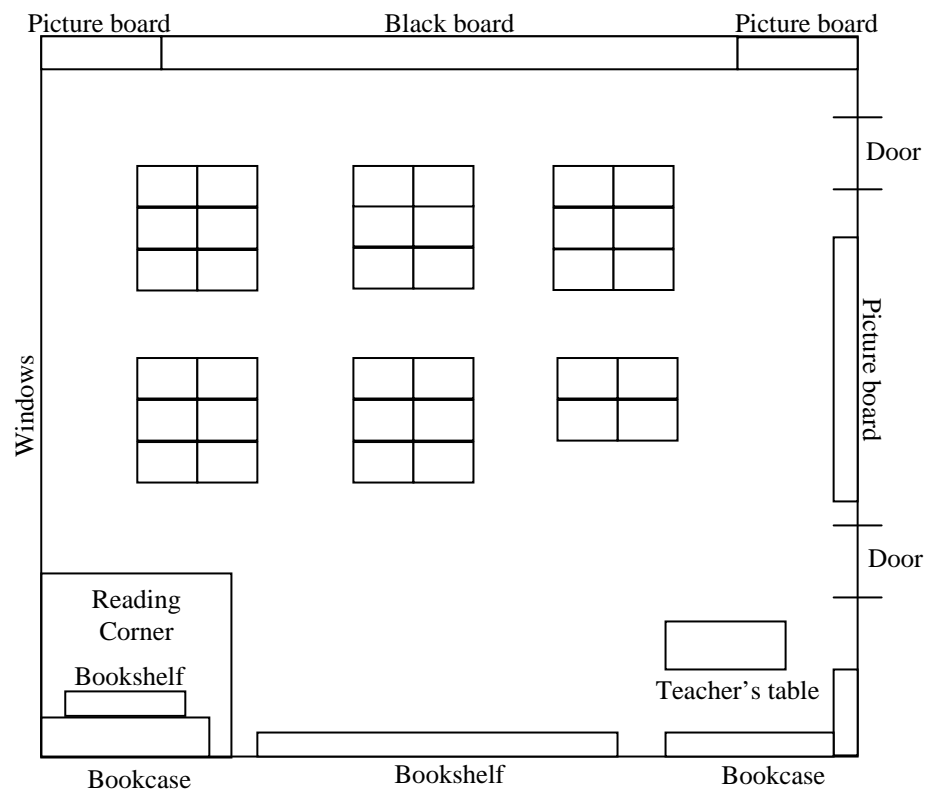


Figure 5.4 Ms. Napar's Classroom Setting After the program

There were posters of pictures and information on the walls and the boards around the classroom and a reading corner for students to spend their free time sitting on the floor and reading some interesting books similar to the setting in the 2004 academic year.

2.4.2 Introductory

Before attending the program, Ms. Napar started with motivating students' interest in a learning topic. She mainly used classroom discussion with some learning media such as pictures, and songs, singing a song related to the topic. The

discussion was focused on students' prior knowledge related to learning topics. For example, she used pictures of the human body to discuss human organs with students and led students in singing a song about human organs.

After attending the program, Ms. Napar started the lesson by motivating students' interest in the learning topic. She used classroom discussion with some learning media related to the topic. The discussion was focused on students' prior knowledge relating to the learning topic. For teaching the topic of electrical energy from a dry cell, she showed a flashlight to the whole class and asked students to discuss the importance of a flashlight.

2.4.3 Teaching and learning activities

Before attending the program, Ms. Napar led students in discussing a learning topic and a concept. Then, she gave them an explanation of the learning concept. For example, Ms. Napar asked students to explain the functions of some human organs such as hands, eyes, ears. Then, she explained the importance of human organs and how to take care our organs. She used a game to ensure students' knowledge of the name of each organ. For example, Ms. Napar asked one student to come in front of the class and lead classmates to touch their organs following the name which was called out.

After attending the program, Ms. Napar led students in a discussion on a learning concept with demonstration and students' observation. For this topic, Ms. Napar gave a flashlight to one student who sat at the front, and asked the student to turn it on. Other students observed and found that there was no light. Then, Ms. Napar led students to discuss the possible causes for the flashlight having no light. The whole class concluded that there was no dry cell. Ms. Napar showed two dry cells to the whole class and put them into a flashlight. She gave the flashlight to another student to turn it on. Other students observed and found that it still did not have light. Ms. Napar led students to discuss the possible causes again until the whole class came to conclusions about the electric circuit of dry cell. Ms. Napar put two dry cells in the

flashlight with the correct circuit and gave it to another student to turn on. Other students observed and found that it had light this time.

2.4.4 Conclusion

Before attending the program, Ms. Napar used picture drawing to ensure students' understanding of the concept. For example, she had each student drawing and coloring a picture of one favorite organ and writing its name under the picture.

After attending the program, Ms. Napar led students to discuss and reach conclusions about the scientific concepts. She used student's worksheets for the students to practice recording data from observation and conclude the results. For this topic, after they had finished the discussion, she gave students worksheets and asked them to complete the table according to what they observed from the demonstration and draw conclusions about the results.

2.5 Factors' Affecting Teacher's Teaching of the Nature of Science

From the interview before program development and implementation, Ms. Napar described her perception of factors which affected her science teaching in two major topics discussed below.

2.5.1 Readiness of students and classroom control

Ms. Napar mentioned that students' lack of attention and short concentration made her waste time trying to motivate and control them. She also noted that students' slow working affected her teaching schedule. Thus, she could not finish science teaching and learning activities completely.

2.5.2 Teaching experiences and skills

Ms. Napar noted that because of not majoring in science, she was not skillful in teaching scientific process. She thought that she had only a fair skill level in teaching science content.

2.6 Perspectives on the Program

From the interview after completion of the program, Ms. Napar discussed her perspectives on what she had learnt from attending the program, the advantages of the program, and the disadvantages of the program. These are discussed below

2.6.1 What teacher had learnt from attending the program

What Ms. Napar had learnt from the program could be divided into two major groups: concepts of the Nature of Science, and teaching and learning approaches.

(1) Concepts of the Nature of Science

Ms. Napar mentioned that before she attended the program, she thought that science was a hard subject. She used to teach science only according to its subject contents. She had never thought about the Nature of Science. Attending the program made her think differently about what she used to know in science content and in the text books. She thought that she knew more about the background and source of scientific content that she was teaching. She also mentioned that from the training program she had a guideline for developing her teaching ability and attitudes toward science teaching consistently.

(2) Teaching and learning approaches

Ms. Napar had learnt more about teaching and learning approaches from the program in several issues. These are listed below.

- Knowing more about technique in setting hypotheses

- Appreciation of the use of the process of scientific experiment and observation in teaching various science topics
- Appreciation of showing scientists' biography and their work in science teaching for students to appreciate the importance of scientists and develop their scientific attitudes

2.6.2 Advantages of the program

Ms. Napar expressed her opinion that the training activities were interesting and could be applied in teaching students, especially the 'inquiry activity' in session 2. It was good to have various teaching and learning methods both in individual study and group work. She mentioned that this training program could support her need for development. This is because she had a chance to do practical activities which were better than only watching a presentation as in other seminars. She thought that setting the training program in the school was an advantage. This was because the school had sufficient apparatus for the training and teachers did not have to travel.

2.6.3 Disadvantages of the program

Ms. Napar mentioned that the time for training as after school was not suitable. This was because teachers were busy and had meetings after school. It made many people miss the training class. Ms. Napar suggested that the training program should be held before semester closed when teachers were free, such as after teachers had already finished giving students their grades. The training program should be run continuously for a day or 2-3 days. Ms. Napar also suggested that there should be training activities out doors so teachers could be alert.

3. Case 3: Ms. Juntra

3.1 Teacher's Background and Participation in the Training Program

Ms. Juntra (pseudonym) was a Grade 1 classroom teacher taking responsibility as the head of Grade 1 classroom teachers. She graduated from a faculty of Education, majoring in educational technology and innovation. Before the 2004 academic year, she had more than ten years teaching experience in primary schools but had no experience in teaching science. This academic year was her first year teaching science as an individual core subject. She also had to teach almost all other core subjects. In the questionnaire, she responded that she liked science because science is reasonable, but she did not like to teach science.

In the 2005 academic year, Ms. Juntra was a Grade 1 classroom teacher and taught in the same classroom as in the 2004 academic year. She taught all subjects including science. She taught science two periods per week. Ms. Juntra could not attend the program continuously. She missed the fourth to six sessions, and the eighth and ninth sessions of the program. This was because she was a head teacher of Grade 1 level and she usually had after school meetings with school administrators. When she attended the program, she was a leader who usually began the discussions or answered the questions. She seemed to enjoy sharing her ideas, experiences and asking questions of the facilitator as well as having dialogue with the other teachers in the whole program to make it a friendly environment. When working in groups or in pairs, she usually worked in a pair with a peer who was not participating in the research. She usually let her peer be the presenter for her group.

3.2 Teacher's Understanding of the Concepts of the Nature of Science

From the statistical analysis of the whole rating scale part of NOSI questionnaire, Ms. Juntra's mean score of the all question items before and after attending the training program are summarized and shown in Table 5.5 below.

Table 5.5 Ms. Juntra's Mean Score of all Question Items Before and After Attending the Program

Academic Year	Period	Mean Score
2004	Before the Program	3.423
2005	At the first session of the Program	3.269
	After the Program	3.346

From the table, it could be inferred that, on the whole, before attending the training program Ms. Juntra had both traditional and contemporary views on the concepts of the Nature of Science. At the first session of the program Ms. Juntra had a more traditional view but after attending the program her view appeared to be more contemporary.

Ms. Juntra's responses to 29 rating scale items of the Nature of Science statements before and after attending the program are shown in Table 5.6 below. 'X' refers to the position of her agreement on the rating scale before and after attending the program. They also show her point of view on each statement in the range of traditional to contemporary view or in the range of misconception to right conceptions. 'O' refers to the position of her agreement on the rating scale in the first training session. If her agreement both at the first training session and after the program are in the same position, the symbol, '⊗' is presented.

Table 5.6 Ms. Juntra's Responses to the Nature of Science Statements Before and After Attending the Program

Statements		Strongly agree	agree	Neutral	disagree	Strongly disagree
1	Science is only a body of knowledge which explains concrete things, natural phenomena, and the world around us.	Traditional		Contemporary		
		<i>Before</i>		←-----X-----→		
		<i>At 1st Period & After</i>		←-----X-----O-----→		
2	Science is a process of exploring the unknown and discovering new things about our world and universe and how they work.	Contemporary			Traditional	
		<i>Before</i>			←-----X-----→	
		<i>At 1st Period & After</i>			←-----⊗-----→	
3	Science is inventing and designing things and finding out ways to make people's lives better.	Misconception Naïve		Right		
		<i>Before</i>		←-----X-----→		
		<i>At 1st Period & After</i>		←X-----O-----→		
4	Scientific knowledge is discovered by scientists who make observations of the world and carefully record and organize the facts or truths in a systematic way.	Traditional		Contemporary		
		<i>Before</i>		←-----X-----→		
		<i>At 1st Period & After</i>		←-----X-----O-----→		
5	Scientific knowledge is generated by scientists who attempt to explain and predict the natural phenomena based on empirical evidence and logical reasoning.	Contemporary		Traditional		
		<i>Before</i>		←-----X-----→		
		<i>At 1st Period & After</i>		←-----X-----O-----→		
6	We can trust in scientific knowledge because it is confirmed by scientific method, scientific experiments and approved by scientific community.	Contemporary		Traditional		
		<i>Before</i>		←-----X-----→		
		<i>At 1st Period & After</i>		←-----⊗-----→		
7	The words facts, concepts, principles, laws and theories in science have the same meaning when being used in our daily lives.	Misconception Naïve		Right		
		<i>Before</i>		←-----X-----→		
		<i>At 1st Period & After</i>		←-----⊗-----→		
8	Scientific facts come from observation and experiments, and then, always become scientific theories that, in turn, become laws.	Misconception Naïve		Right		
		<i>Before</i>		←-----X-----→		
		<i>At 1st Period & After</i>		←-----X-----O-----→		
9	We can not have questions about scientific theories and laws. They are 100% true according to reality and unchangeable. We have to remember and use them.	Traditional		Contemporary		
		<i>Before</i>		←-----X-----→		
		<i>At 1st Period & After</i>		←-----⊗-----→		
10	When scientists make arguments, their personal bias does not have an influence.	Traditional		Contemporary		
		<i>Before</i>		←-----X-----→		
		<i>At 1st Period & After</i>		←-----X-----O-----→		

Table 5.6 (Continued)

	Statements	Strongly agree	agree	Neutral	disagree	Strongly disagree
11	Scientific knowledge can change if there is more evidence.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
12	We make sense of the world by careful and systematic study for making reasonable explanations of phenomena.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----X-----O-----→				
13	The world and universe occur in consistent patterns, we can discover these patterns by using the intellect and the aid of instruments.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
14	Science is the most powerful way of understanding and discovering the truth of the natural world.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
15	Some matters cannot be examined usefully in a scientific way.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
16	Science can not completely explain the world and how it works, but, it can give accurate approximations.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----X-----O-----→				
17	Scientists have no ideas about results before doing observations or experiments.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
18	Scientists do experiments to confirm scientific knowledge as proving the truth or falsehood of this knowledge.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
19	Every scientist always does scientific investigations in the same way, as a fixed set of steps, to gain their scientific knowledge.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----O-----X-----→				
20	Scientists try to explain and predict phenomena as the most accurate to the reality, although they know that they can not discover the absolute truth.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----O-----X-----→				
21	We can not use imagination and creativity to get scientific knowledge.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				

Table 5.6 (Continued)

	Statements	Strongly agree	agree	Neutral	disagree	Strongly disagree
22	Scientists need to communicate their scientific results and require peer review.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
23	Scientists always work individually in the laboratory, and social affairs outside do not affect their work.	Traditional			Contemporary	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----X-----O-----→				
24	Scientists are people like every bodyelse and participate in community both as specialists and as citizens.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
25	Science and technology affects society on the one hand, society affects science and technology on the other hand.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
26	Technology gets ideas from science and science gets new processes and instruments from technology.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
27	Scientists can do scientific research by do not have to give much consideration to ethical principles.	Traditional			Contemporary	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
28	Science is only scientists' work. Other groups of people in society can not participate.	Traditional			Contemporary	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
29	Today's scientists develop scientific knowledge from previous knowledge according to history.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----X-----O-----→				

Ms. Juntra's conceptions of the Nature of Science before, during and after attending the program are described in detail within five major aspects of the Nature of Science: definitions of science, scientific knowledge; development of scientific knowledge; introduction to science, technology and society; characteristics of science and scientific attitudes.

3.2.1 Definitions of Science

Before attending the program, Table 5.6 shows Ms. Juntra's responses to items 1 and 2 of the NOSI questionnaire. She agreed with both the traditional and contemporary views of the definitions of science. Thus, it could be inferred that she had mixed or blended views of the definition of science. She seemed to view science as both a body of knowledge and a process for understanding the world.

In the open-ended part of the questionnaire Ms. Juntra mentioned that the subject of science was related to scientific process and process skills, and reasoning. Thus, she seemed to adopt a contemporary view of science as a process in her classroom teaching.

For item 3, Ms. Juntra agreed that science is inventing and designing things and finding out ways to make people's lives better. From this it could be inferred that Ms. Juntra had an alternative conception of the differences between science and technology. She seemed to view science in the terms of technology. It could also be inferred that she would have a utilitarian view that the aim of science is to help find ways to make people's lives better.

In the first session of the program, there was a discussion about the teacher's personal views on science and teaching science. Ms. Juntra's expressed personal idea was that science helped us in solving problems and used reasoning. Thus, she seemed to view science as a process.

After attending the program, Ms. Juntra's response to items 1 and 2 of the NOSI questionnaire showed that she changed from disagree to neutral about the traditional view of the definitions of science. She agreed with contemporary view of the definitions of science. Thus, she seemed to view science as a process to understand the world rather than a body of knowledge.

The interview after the program also found that Ms. Juntra believed that science was a process. As she said:

... In my opinion, as I received [from the training program], science is inquiry for knowledge and searching for truth ... science is about knowing how to use reasons, knowing how to investigate, study, do experiments and apply the results for oneself (Ms. Juntra).

For item 3 of NOSI questionnaire, Ms. Juntra more strongly agreed that science is inventing and designing things and finding out ways to make people's lives better. From this it could be inferred that Ms. Juntra had misconception of the different definitions of science and technology. She seemed to view science in terms of technology. It could also be inferred that she would have a utilitarian view which thought that the aim of science was to help finding ways to make people's lives better.

3.2.2 Scientific Knowledge

(1) Source of Scientific Knowledge

Before attending the program, Ms. Juntra responded to questionnaire items 4 and 5 by choosing neutral to the traditional view of the source of scientific knowledge being that scientific knowledge was discovered by scientists through observation and scientific methods. She agreed with the contemporary view of the source of scientific knowledge that scientific knowledge was generated by scientists through their process of thought based on empirical evidence. Thus, Ms. Juntra seemed to have a more contemporary view of the source of scientific knowledge than traditional view in this aspect.

After attending the program, Ms. Juntra's responses to questionnaire items 4 and 5 agreed more with the traditional view of the source of scientific knowledge that scientific knowledge is discovered by scientists through observation and scientific method. She also agreed more with the contemporary view

of the source of scientific knowledge that scientific knowledge is generated by scientists through their process of thought based on empirical evidence. From this it could be inferred that Ms. Juntra seemed to regard scientific knowledge as coming from both discovery and generation by scientists.

(2) Nature of Scientific Knowledge

There are three sub-points of the nature of scientific knowledge focused on in this research.

i) Validity of Scientific Knowledge

Before attending the program, Ms. Juntra's response to a statement about validity of scientific knowledge on the NOSI questionnaire is shown in item 6. She agreed with the contemporary view which emphasized that the validity of scientific knowledge was based on both confirmation of empirical evidence through scientific method and experiments, and approval of the scientific community.

After attending the program, she still agreed with the contemporary view which emphasized that validity of scientific knowledge is based on both confirmation of empirical evidence through scientific method and experiments, and approval by the scientific community.

ii) Definitions of Different Kinds of Scientific Knowledge

Before attending the program, Ms. Juntra's responses to statements about different kinds of scientific knowledge on the NOSI questionnaire are shown in items 7 and 8. She chose neutral for these items. This could mean that she had a naïve understanding about the difference between using the words facts, concepts, principles, laws and theories in science and using these words in daily life. She also had a naïve understanding that scientific facts could be simply developed to become scientific theories which then, in turn, become scientific laws.

After attending the program, Ms. Juntra still agreed with item 7 and agreed more with item 8. This could mean that she had an alternative conception about the difference between the use of the words facts, concepts, principles, laws and theories in science and using these words in our daily lives. She also had an alternative conception that scientific facts could be simply developed to become scientific theories which then become scientific laws.

iii) Specific Characteristics of Scientific Knowledge

Before attending the program, Ms. Juntra's responses to statements about specific characteristics of scientific knowledge on the NOSI questionnaire are shown in items 9 to 11. Ms. Juntra chose neutral to item 9 and agreed with items 10 and 11. From these responses it could be inferred that Ms. Juntra neither agreed nor disagreed with the traditional view which stated that science is precise, is not tentative, and is a representation of the truth. She agreed with the contemporary view that scientific knowledge was changeable. She agreed with the traditional view which lacked any concern about the subjective and perceptually bonded characteristics of scientific knowledge.

After attending the program, Ms. Juntra still strongly disagreed with item 9, agreed more with item 10 and still agreed with item 11. From these responses, it could be inferred that Ms. Juntra agreed with the contemporary view which recognizes that science is tentative, changeable, and empirical-based. She agreed with the traditional view which had no concern about subjective and perceptually bonded characteristics of scientific knowledge.

3.2.3 Development of Scientific Knowledge

(1) Scientific World View and Basic Assumption of the Nature of Science

Before attending the program, Ms. Juntra's responses to statements about the scientific world view and basic assumptions of the Nature of Science on the NOSI questionnaire are shown in items 12 to 16. Ms. Juntra agreed with item 12 and disagreed with item 13. From this it could be inferred that she agreed with the contemporary view of science which holds that the world can be understood by human intellect and the construction of reasonable explanations rather than just the discovery of the existing patterns of nature. Ms. Juntra chose neutral to items 14, 15, and 16. From this it could be inferred that she neither agreed nor disagreed with the traditional view which emphasizes that science could provide absolute certainty or discover the truth of the natural world and the contemporary view which believes that science and scientific inquiry has inherent limitations.

After attending the program, Ms. Juntra agreed more with item 12. This could mean that she had a contemporary view that the world could be understood by human intellect and its construction of reasonable explanations. Ms. Juntra still agreed with item 13. From this it could be inferred that she had a traditional view that the world and universe occur in consistent patterns and that these patterns can be discovered. Ms. Juntra's response to item 14 showed that she still had traditional views which emphasize that science could provide absolute certainty or discover the truth of the natural world. Ms. Juntra still agreed with item 15 and agreed more with item 16. From this it could be inferred that she had contemporary views which believes there are inherent limitations in science and scientific inquiry.

(2) Scientific Method and Process

Before attending the program, Ms. Juntra's responses to statements about scientific method and process on the NOSI questionnaire are shown

in items 17 and 18 of Table 5.6. It was found that Ms. Juntra chose neutral as her response to item 17. This means that she neither agreed nor disagreed with the contemporary view which emphasizes that scientific method and process is theory-laden. She agreed with item 18. This could imply that she agreed with the traditional view which emphasized that scientific experiments or scientific method are the means to generate and verify truth in scientific knowledge as true or false.

In the second session of the training program, there was a reading of the 'Inquiry Story' and articles of recent scientists' work. Ms. Juntra mentioned that she had learned more about scientist's observation and experimentation.

While she participated in the program, Ms. Juntra seemed to be interested in the discussion about some scientific process skills after reading the 'Inquiry Story' and articles of recent scientists' work and while designing scientific experiments for free falling objects. In the second session, Ms. Juntra mentioned that she had learnt more about hypotheses. In the third session, Ms. Juntra discussed control variables and repeat experiments. In sessions 10 to 12, Ms. Juntra could identify the scientific processes and process skills embedded in sample lesson plans. These processes and skills were exploration, observation, data recording, results presentation, discussion comparison, classification, communication, and experimentation. When designing the lesson plan in session 12, Ms. Juntra emphasized developing her students' science process skills in observation and classification.

After attending the program, Ms. Juntra wrote in her journal that she had learnt more about the concepts of scientific process, prediction, and error in science. Her responses to statements about scientific method and process on the NOSI questionnaire in items 17 and 18 showed that she still agreed with both items. This means that she agreed with the traditional view which holds that scientific method and process is not theory-laden and emphasizes that scientific experiments or scientific

method are the means to generate and verify truth in scientific knowledge as true or false.

(3) Characteristics of Scientific Inquiry

Before attending the program, Ms. Juntra's responses to statements about the characteristics of scientific inquiry in the NOSI questionnaire are shown in items 19 to 22 of Table 5.6. Ms. Juntra's disagreement with item 19 could mean that she agrees with the contemporary view which holds that scientists do not use only a single scientific method, or fixed sets of orderly and logical steps, as tools for their research. Ms. Juntra chose neutral as her response to item 20. From this it could be inferred that she neither agreed nor disagreed with the contemporary view which stated science was an attempt to explain and predict phenomena as the most accurate description of reality within its limitation to discover or reveal the absolute truth. Ms. Juntra agreed with item 21. This could mean that she agreed with the traditional view which lacked a concern for the role of imagination and creativity in scientific inquiry. For item 22, Ms. Juntra agreed with this item. This could imply that she agreed with the contemporary view which emphasized the role of communication of scientific results in contributing to scientific inquiry. In the open-ended part of the questionnaire, Ms. Juntra mentioned some processes and skills relating to scientific inquiry: thinking and reasoning, observation, experimentation, and problem-solving.

In the seventh session, there was a discussion about how the good characteristics of science teaching approaches related to the Nature of Science. Ms. Juntra discussed the concept that with learning by exploration in groups, students would learn to share knowledge with their peers. It seemed that she recognized the role of communication in science.

After the program, Ms. Juntra's journal writing indicated that she recognized the components of scientific inquiry: observation, investigation, exploration, classification, creativity, reasoning and communication. She also

mentioned in the interview after the program that she had learnt about the problem-solving process which she could apply in her career.

After attending the program, Ms. Juntra's increased disagreement with item 19 of the NOSI questionnaire could mean that she agreed with the contemporary view which is that scientists do not use only a single scientific method, or fixed sets of orderly and logical steps, as tools for their research. Ms. Juntra disagreed more with item 20. This could imply that she agreed with the traditional view which does not believe that science is an attempt to explain and predict phenomena as the most accurate reflection of reality with concern for its limitation to discover or reveal the absolute truth. When Ms. Juntra chose to disagree with this item, she thought that science must try to search for the absolute or certain truth. It should use various ways to identify the absolute truth. Ms. Juntra still agreed with item 21. This could mean that she agreed with the traditional view which lacked a concern for the role of imagination and creativity in scientific inquiry. For item 22, Ms. Juntra still agreed with this item. From this it could be inferred that she agreed with the contemporary view which emphasized the role of scientific results communication in contributing to scientific inquiry.

3.2.4 Interrelation between Science, Technology, and Society

For this major aspect, Ms. Juntra's understanding was investigated as a whole and as particular points, interrelation between science and technology, and interrelation between science and society.

For the whole aspect of interrelation between science, technology, and society, before attending the program, Ms. Juntra agreed with item 25 on Table 5.6. From this it could be inferred that she agreed with the contemporary view which recognizes the interrelation between science, technology, and society.

After attending the program, Ms. Juntra still agreed with item 25 on the Table 5.6. From this it could be inferred that she agreed with the contemporary view which recognized the interrelation between science, technology, and society.

For particular points, Ms. Juntra's responses to the questionnaire are shown and discussed below.

(1) Interrelation between Science and Technology

Before attending the program, Ms. Juntra agreed with a statement about the interrelation between science and technology on the NOSI questionnaire, item 26 on Table 5.6. This could imply that she agreed with the contemporary view concerning the relationship between science and technology.

After attending the program, Ms. Juntra strongly agreed with item 26 of NOSI questionnaire. From this it could be inferred that she still agreed with the contemporary view which is concerned with the relationship between science and technology.

(2) Interrelation between Science and Society

Before attending the program, Ms. Juntra's responses to statements about the interrelation between science and society on the NOSI questionnaire are shown in items 23, 24, and 27 to 29 of Table 5.6. Ms. Juntra disagreed with item 23. This implies that she agreed with the contemporary view which considers that scientific enterprise is not isolated from society and recognizes that science is a socially complex activity. Ms. Juntra's neutral response to item 24 showed that she neither agreed nor disagreed with the contemporary view which believes that scientists are not separated from humanity and society and science is part of intellectual, social, and cultural traditions. From Ms. Juntra's disagreement with items 27 and 28 could be inferred that she had a contemporary view which held that scientists' work is not ethics free and that people from all cultures contribute to

science. For item 29, Ms. Juntra chose neutral. From this it could be inferred that she neither agreed nor disagreed with the contemporary view which concerns itself with the historical aspect of science or the evolutionary and revolutionary characteristics of science.

After attending the program, Ms. Juntra agreed more with item 23. This could imply that she agreed with the traditional view which considered that scientific enterprise is isolated from society and lacks a concern that science is a socially complex activity. Ms. Juntra's response as 'still agree' to item 24 showed that she agreed with the contemporary view which holds that scientists are not separated from humanity and society and science is part of intellectual, social, and cultural traditions. Ms. Juntra still disagreed with items 27 and 28. From this it could be inferred that she had a contemporary view which held that scientists' work is not ethics free and people from all cultures contributed to science. For item 29, Ms. Juntra agreed more with this item. This could imply that she agreed with the contemporary view which believes in the historical aspect of science or evolutionary and revolutionary characteristics of science.

3.2.5 Characteristics of Scientists and Scientific Attitudes

Before attending the program, from the open-ended part of the questionnaire, Ms. Juntra could not give an answer relating to the question about scientific attitudes (question number 4). She did not seem to know the meaning and components of scientific attitudes or habits of mind. However, from her responses to other open-ended questions, it was found that she emphasized the development of students' rational thinking and collaborative learning. This rational thinking could be referred to as one of scientific attitude in the aspect of reasoning. Collaborative learning could be related to the open-minded aspect of scientific attitude.

While attending the program, it was found that Ms. Juntra recognized the reasoning aspect of scientific attitude. In the seventh session, she discussed the characteristics of good science teaching approaches noting that teachers

should develop students' use of reason and querying what the teacher told them before investigating and proving it themselves. Ms. Jutra also recognized the curiosity aspect of the scientific attitude as she mentioned in the discussion about scientific attitude which was embedded in the sample lesson plan in the twelfth session.

Ms. Juntra emphasized the broad-minded aspect of scientific attitude, mentioning both in her journal writing and during an interview after the program. She thought that scientists should be open-minded when doing investigations, saying that:

... In my opinion, I think that when they [scientists] do investigation, they should open mind, right? ... [We should] have broad mind, although sometimes it may be against our feeling or our group, we should accept them, right? (Ms. Juntra).

3.3 Teacher's Understandings of Instructional Approaches to the Nature of Science

In this section, data from interviews, classroom observation, questionnaire responses and documents were gathered and analyzed to identify Ms. Juntra's understanding of instructional approaches related to the Nature of Science before and after attending the program. The findings are presented in two sub-topics; objectives of science teaching, and teaching approaches.

3.3.1 Objectives of science teaching

Before attending the program, Ms. Juntra stated in questionnaire responses that her objective when science teaching was to develop students' abilities in performing scientific processes and skills. She thought that in learning science, students should be encouraged to express their thoughts. The important topic in her science teaching was conservation of the environment. She emphasized developing

students' skills in rational thinking, observation, experimentation, and problem-solving.

In the first session of the program, before starting the training activities, in the open-ended part of the NOSI questionnaire Ms. Juntra was asked to write down her aims in science teaching and learning with her reasons. She stated that her science teaching was to develop students' abilities in using logic, to learn about living and non-living things, and to learn about classification and investigation. This was to teach students to be rational, skeptical, and eager to search for the truth.

During the program, in the first session, Ms. Juntra seemed to be impressed with the 'best practice' teacher's aim to develop students to be scientists. She joined in the discussion and seemed to agree with the idea of the class majority which thought that this aim was not suitable for science teaching and learning in lower primary school level. She thought that the aim of science teaching was so students could use science in living and in solving problems. In the seventh session, Ms. Juntra joined in the discussion about the relationship between the aims of science teaching and teacher's views on science. She seemed to recognize that the objectives of science teaching should be related to teachers' views of science. She mentioned that she thought that science was about problem-solving. So, she aimed to teach students to be able to investigate or search for problematic truth.

After the program, Ms. Juntra was asked to review her answer on the open-ended part of the NOSI questionnaire and, if she wanted, to rewrite her aims in science teaching and learning with her reasons. It was found that Ms. Juntra changed her answers. The aims of her science teaching were now changing students' beliefs and developing students' reasoning, learning scientific process and using it in daily life, and understanding various things. This was to teach students to have full competency.

3.3.2 Teaching approaches

Before attending the program, Ms. Juntra considered that science teaching and learning activities should be set based on a student-centered approach and based on subject contents. Students should learn to understand how to use rational thinking, to classify, and to research. They should learn by self study and learn from things that surround them. They should learn through researching, experimenting, concluding, and reasoning.

In her science teaching, Ms. Juntra used questioning and classroom discussion as her major approaches. She also had students working individually and in groups. Her classroom discussions emphasized scientific facts and concepts, and students' attitudes. She also taught by integrating science with other subjects in some topics which had related or similar contents. It was found that instructional media and resources used in her teaching were students' workbooks, pictures, drawing paper and crayon, other students, and some practical and simple things in the school grounds.

To assess students' learning of science, Ms. Juntra used questioning, observation of performance while engaging in science class activities, correcting work, and paper-pencil tests after they had finished topics.

In the first session of the program, before starting the training activities, in the open-ended part of the NOSI questionnaire Ms. Juntra was asked to write down her teaching approaches for the Nature of Science. She stated that science teaching approaches were self-study; learning from things surrounding us; and learning from investigation, experimentation, conclusion, and reasoning.

During the program, Ms. Juntra joined the discussion of students' learning of science and the characteristics of good science teaching in the seventh and tenth sessions. Ms. Juntra thought students should learn science by doing experiments and investigations by themselves with the guidance of teachers. Teachers should teach from natural and real objects, teach students to know how to use reason. Teachers should use group work in exploration so students would share their knowledge.

Teachers should use experiments or demonstrations which were meaningful and interesting for students. In the tenth session, there was an activity of analyzing sample lesson plans. Ms. Juntra could classify scientific process, scientific process skills, and scientific attitudes embedded in the sample lesson plan. In a discussion about how to develop students' understanding of the Nature of Science, Ms. Juntra mentioned that teachers could teach students to do investigations or self study. Then, teachers should guide students in discussion to see whether or not they had a correct understanding of science from what they learned by themselves. In the twelfth session Ms. Juntra's lesson plan emphasized developing students' scientific concepts and science process skills including observation and classification.

After the program, Ms. Juntra was asked to review her answers on the open-ended part of the NOSI questionnaire and she was asked, if she wanted, to rewrite her teaching approaches for the Nature of Science. Ms. Juntra wrote new answers commenting that her teaching approach was to use a scientific process in conjunction with other subject matters. In the interview after the program, Ms. Juntra was asked about the teaching approaches for the Nature of Science and how she thought about using reflective questions, and what she did that was similar to scientists' behaviour. She seemed to emphasize using science process and scientific process skills in science teaching, commenting that students should do practical activities such as investigation, discussion, setting hypotheses, and experimentation. For the idea of using reflective questions or discussion to indicate concepts of the Nature of Science and concepts of scientific process to students, Ms. Juntra thought that Grade 1 students were too young to discuss the concepts of scientific process, scientific process skills, and characteristics of scientists. They would not understand. Teachers could only lead them in hands-on activities such as observation following instruction, but could not lead students to discuss the process or characteristics of scientific observation.

3.4 Teaching of the Nature of Science

From classroom observation, Ms. Juntra's process of science teaching before and after attending the program is summarized and illustrated in four sub-

topics: classroom setting, introduction, teaching and learning activities, and conclusions.

3.4.1 Classroom setting

Before attending the program, Ms. Juntra generally taught science in her classroom. She set students' desks in pairs and rows. There were approximately 30 students in her class. The setting is illustrated in Figure 5.5 below.

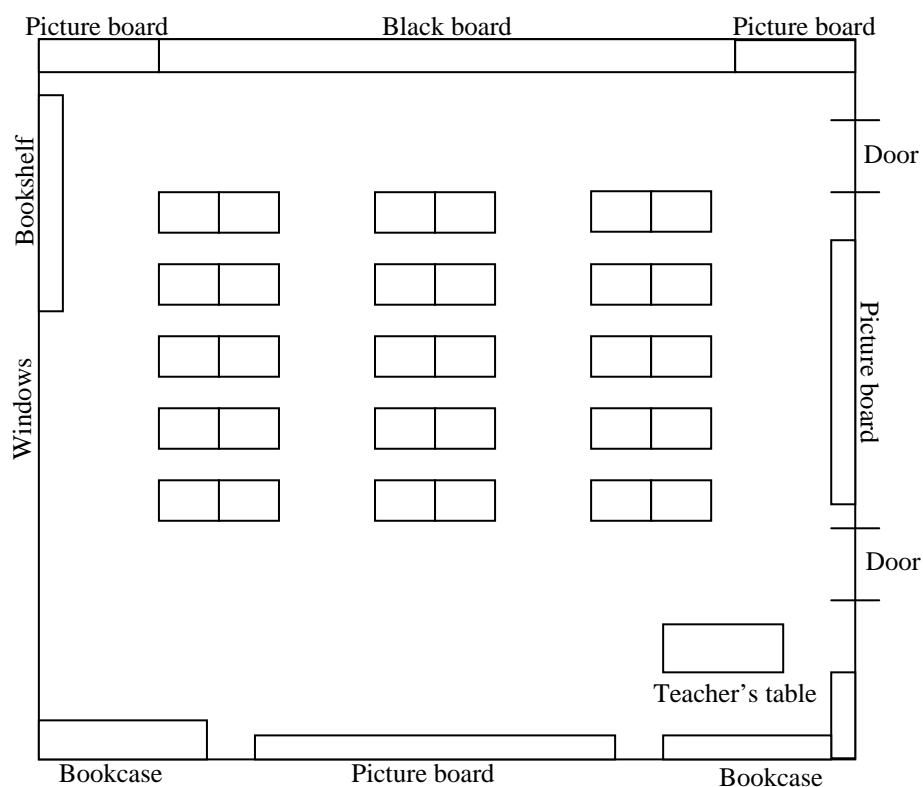


Figure 5.5 Ms. Juntra's Classroom Setting Before the Program

On the walls and the boards around the classroom, there were posters of students' work, pictures and learning information on the topics of important days, health, numeric characters, and Thai alphabetic characters.

In the 2005 academic year, after attending the program, Ms. Juntra taught science in the same classroom as the 2004 academic year. Ms. Juntra taught

science in her classroom. She set students' desks in groups. There were approximately 35 students in her class. The setting is illustrated in Figure 5.6 below.

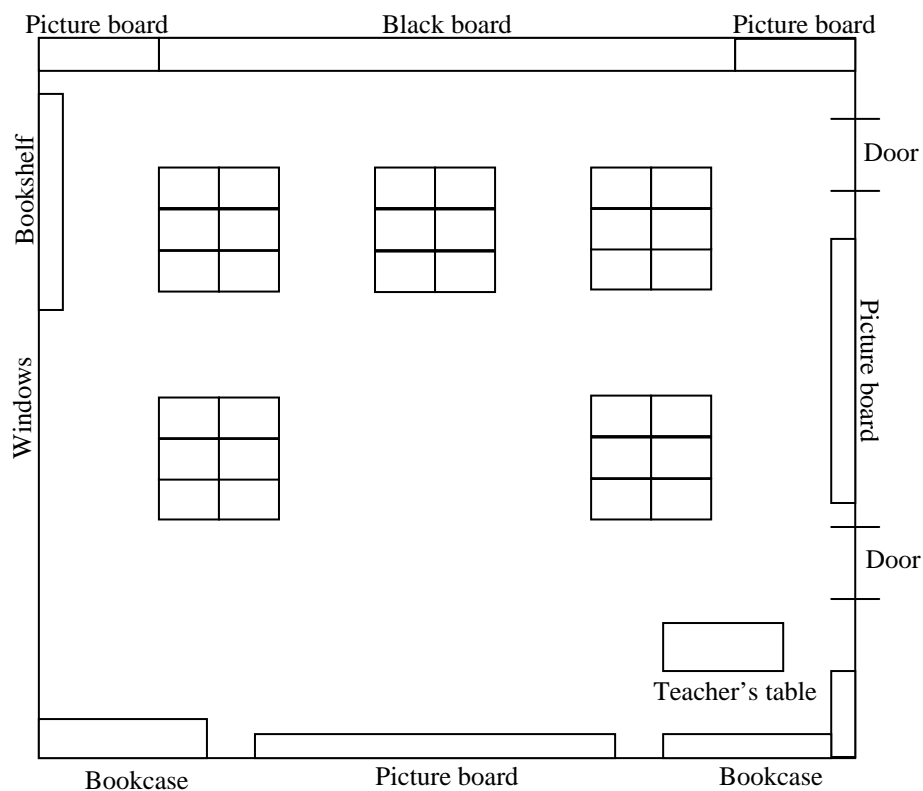


Figure 5.6 Ms. Juntra's Classroom Setting After the Program

There were posters of pictures and information on the walls and the boards around the classroom and a reading corner for students to spend their free time sitting on the floor and reading some interesting books similar to the setting in the 2004 academic year.

3.4.2 Introductory

Before attending the program, Ms. Juntra started with motivating students' interest in a learning topic. She mainly used classroom discussion with some learning resources such as a story in students' workbooks. The discussion was focused on students' prior knowledge related to the learning topic. For example, she led students reading a story about a rabbit and a rock. Then she asked students to

compare the difference between a rabbit and a rock before linking the discussion to the concept of living and non-living things.

After attending the program, using classroom discussion, Ms. Juntra started by motivating students' interest in the learning topic. The discussion was focused on students' prior knowledge relating to the learning topic. For the topic of soil components, she led students in discussion about the importance of soil and characteristics of soil from their own experience.

3.4.3 Teaching and learning activities

Before attending the program, Ms. Juntra led students to discuss a learning topic and concept. She questioned students and had them answer. She led her students to conclude a concept from the discussion. She used pictures and diagram drawing to assist in her instruction and conclusion of the concepts. She used discussion and explanation to introduce a new concept and link the new concept with the previous concept. For example, she asked students to explain the major characteristics of living and non-living things. While students were discussing and explaining, Ms. Juntra drew pictures and wrote keywords on the blackboard to draw conclusions about the concept. Then, she asked students to discuss their surroundings and introduced the new word, 'environment', to her students. Ms. Juntra discussed this with her students and defined the word 'environment'.

Ms. Juntra used social events such as World Environment Day and used the school bill-board as a teaching and learning resource to assist her teaching. For example, she brought students to see some school bill-boards on the building which had pictures of natural scenery and a poem about conservation of the environment for World Environment Day. Then, she led students in a discussion about the characteristics of a good environment and how to conserve the environment.

After attending the program, Ms. Juntra let students do exploration. She gave materials for each group of students and led students in activities following

her instructions step by step. For this topic, the activities were aimed at exploring the components of soil. The activities were started by squeezing soil and observing its characteristics. Then, students put soil in water and observed what happened while soil sank in water. After that, students stirred water and observed. After completing the activities, Ms. Juntra led students to discuss the findings as a whole class. Students reported what they observed or found from each step. Ms. Juntra took note of their answers on the black board.

3.4.4 Conclusion

Before attending the program, Ms. Juntra used picture drawings to ensure students' understanding of the concept. For example, she had each student draw and color a picture of a good environment in school or in Thailand.

After attending the program, Ms. Juntra let students draw a concept chart to summarize the understanding of scientific concepts that they gained from the exploration. She drew an outline of the concept chart on the blackboard and asked students to fill the branches of the map. Students read more from their text book and summarized the key words on their chart. For this topic, Ms. Juntra asked students to write a concept chart of what soil is and write one sentence to conclude this subject.

3.5 Factors' Affecting Teacher's Teaching of the Nature of Science

From the interview before the program development and implementation, Ms. Juntra described her perceptions about factors which affected her science teaching in two major topics: readiness of students and parental support.

3.5.1 Readiness of students

Ms. Juntra mentioned that students' lack of ability in reading affected her teaching. She had to guide her students in reading.

3.5.2 Parental support

Ms. Juntra considered that students who had more direct experiences by going outside with their parents seemed to be able to discuss and express their ideas in science class more than students who had less direct experience because of staying at home and watching television.

3.6 Perspectives on the Program

In the interview after completion of the program, Ms. Juntra described her perspectives on what she had learnt from attending the program, the advantages of the program, and the disadvantages of the program. These perspectives are discussed below.

3.6.1 What the teacher had learnt from attending the program

What Ms. Juntra had learnt from the program could be divided into two major groups: concepts of the Nature of Science, and teaching and learning approaches.

(1) Concepts of the Nature of Science

After attending the program, Ms. Juntra said that scientific processes taught in this program were similar to those she had known before. However, this training program helped her in knowing the background of science. She gained an understanding that science was the way to have reasons, to do investigation, to research, to do experiments and apply results for oneself. She thought that she had developed her skeptical attitude. She would not believe in anything easily and would find out its causes. Ms. Juntra shared that she applied this attitude to her career in solving a problem of one student's misbehavior. She thought that she gained an ability to do problem-solving and trial and error many times from attending this training program. She also mentioned that she gained more understanding and felt that

learning science was not boring. She thought we could know the truth and could apply it to daily living. She had good attitudes toward science.

(2) Teaching and learning approaches

Ms. Juntra had learnt more about teaching and learning approaches from the program on several issues. These issues are listed below.

- Appreciation in using scientific process for teaching the Nature of Science
- Appreciation in applying classroom presentation as one of her teaching and learning activities
- Appreciation in applying reading and critical discussion to her mathematics and Thai language teaching and applying scientific process with other subjects

3.6.2 Advantages of the program

Ms. Juntra expressed her opinion that this training program encouraged her in her thinking all the time. She liked to participate in discussions, sharing and presenting her knowledge and ideas.

3.6.3 Disadvantages of the program

Ms. Juntra mentioned that training content was too broad and not suitable for lower primary school level. She would like to learn more about teaching and learning approaches for specific science concepts. There should be training for using scientific equipment and lists of sample teaching and learning activities for some specific science process skills. She mentioned that the language used in training documents was sometimes hard to understand or interpret, especially technical terms such as inquiry and broad-mindedness. She thought that her missing several of the training classes affected her learning and understanding of the training content. She

suggested that the training program should be set in more of a long continuous period. It might be set before or during semester break for five days.

4. Case 4: Ms. Jintana

4.1 Teacher's Background and Participation in the Training Program

Ms. Jintana (pseudonym) was a Grade 1 classroom teacher and took responsibility as office staff in the department of administration of her school. She graduated from a faculty of Education, majoring in teaching social science. She had teaching experience of approximately 12 years and has had one year's experience in teaching science as integrated in Life Experience group of subjects. Ms. Jintana had to teach science as one of the individual core subjects for the first time in the 2004 academic year. She also had to teach another eight core subjects. To the questionnaire and interview, she responded that she liked science and teaching science because science is about natural and surrounding sensible things that we should understand. However, she mentioned that she lacked expertise in teaching science because she did not major in science.

In the 2005 academic year, Ms. Jintana became a Grade 2 classroom teacher. She taught all subjects including science. She taught science two periods per week. Ms. Jintana attended every session of the program. She always jotted the lessons in her workbook. She tried to take part in sharing ideas in the discussions and answering the questions and had the intention of doing every activity. When working in groups or in a pair, she usually worked in a group with two other non-participant teachers. She usually let one of her peers be a presenter to present her group work in front of the class.

4.2 Teacher's Understandings of Conceptions of the Nature of Science

From the statistical analysis of the whole rating scale part of NOSI questionnaire, Ms. Jintana's mean score of the all the question items before and after attending the training program is summarized and shown in Table 5.7 below.

Table 5.7 Ms. Jintana's Mean Score of all Question Items Before and After Attending the Program

Academic Year	Period	Mean Score
2004	Before the Program	3.423
2005	At the first session of the Program	3.346
	After the Program	3.346

From the Table, it could be inferred that, on the whole, before attending the training program Ms. Jintana had both traditional and contemporary views on the concepts of the Nature of Science. At the first session of the program Ms. Jintana had a more traditional view. After attending the program her view appeared to be the same as before attending the program.

Ms. Jintana's responses to the 29 rating scale items of the Nature of Science statements before and after attending the program are shown in Table 5.8 below. 'X' refers to the position of her agreement on the rating scale before and after attending the program. They show her point of view on each statement in the range of traditional to contemporary view or in the range of misconception to right conceptions. 'O' refers to the position of her agreement on the rating scale in the first training session. If her agreement both at the first training period and after the program are in the same position, the symbol, '⊗' is presented.

Table 5.8 Ms. Jintana' s Responses to the Nature of Science Statements Before and After Attending the Program

Statements		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	Science is only a body of knowledge which explains concrete things, natural phenomena, and the world around us.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
2	Science is a process of exploring the unknown and discovering new things about our world and universe and how they work.	Contemporary			Traditional	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
3	Science is inventing and designing things and finding out ways to make people's lives better.	Misconception	Naïve	Right		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
4	Scientific knowledge is discovered by scientists who make observations of the world and carefully record and organize the facts or truths in a systematic way.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
5	Scientific knowledge is generated by scientists who attempt to explain and predict the natural phenomena based on empirical evidence and logical reasoning.	Contemporary			Traditional	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
6	We can trust in scientific knowledge because it is confirmed by scientific method, scientific experiments and approved by scientific community.	Contemporary			Traditional	
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
7	The words facts, concepts, principles, laws and theories in science have the same meaning as when used in our daily lives.	Misconception	Naïve	Right		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
8	Scientific facts come from observation and experiments, and then, always become scientific theories that, in turn, become laws.	Misconception	Naïve	Right		
		<i>Before</i>				
		←X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
9	We can not have questions about scientific theories and laws. They are 100% true according to reality and unchangeable. We have to remember and use them.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
10	When scientists make arguments, they are not influenced by their personal bias.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				

Table 5.8 (Continued)

Statements		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
11	Scientific knowledge can change if there is more evidence.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
12	We make sense of the world by careful and systematic study for making reasonable explanations of phenomena.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
13	The world and universe occur in consistent patterns, we can discover these patterns by using the intellect and the aid of instruments.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
14	Science is the most powerful way of understanding and discovering the truth of the natural world.	Traditional		Contemporary		
		<i>Before</i>				
		←X-----→				
		<i>At 1st Period & After</i>				
		←⊗-----→				
15	Some matters cannot be examined usefully in a scientific way.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
16	Science can not completely explain the world and how it works, but, it can give accurate approximations.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
17	Scientists have no ideas about results before doing observations or experiments.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
18	Scientists do experiments to confirm scientific knowledge, proving the truth or falsehood of this knowledge.	Traditional		Contemporary		
		<i>Before</i>				
		←X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
19	Every scientist always does scientific investigations in the same way, as a fixed set of steps, to gain their scientific knowledge.	Traditional		Contemporary		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
20	Scientists try to explain and predict phenomena as the most accurate to the reality, although they know that they can not discover the absolute truth.	Contemporary		Traditional		
		<i>Before</i>				
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				

Table 5.8 (Continued)

Statements		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
21	We can not use imagination and creativity to get scientific knowledge.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
22	Scientists need to communicate their scientific results and require peer review.	Contemporary <i>Before</i>			Traditional	
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
23	Scientists always work individually in the laboratory, and social affairs outside do not affect their work.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
24	Scientists are people like every bodyelse and participate in community both as specialists and as citizens.	Contemporary <i>Before</i>			Traditional	
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
25	Science and technology affects society on the one hand, society affects science and technology on the other hand.	Contemporary <i>Before</i>			Traditional	
		←X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
26	Technology gets ideas from science and science gets new processes and instruments from technology.	Contemporary <i>Before</i>			Traditional	
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
27	Scientists can do scientific research by do not have to give much consideration to ethical principles.	Traditional <i>Before</i>		Contemporary		
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
28	Science is only scientists' work. Other groups of people in society can not participate.	Traditional <i>Before</i>			Contemporary	
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				
29	Todays' scientists develop scientific knowledge from previous knowledge according to history.	Contemporary <i>Before</i>			Traditional	
		←-----X-----→				
		<i>At 1st Period & After</i>				
		←-----⊗-----→				

Ms. Jintana's conceptions of the Nature of Science before, during and after attending the program are described in detail within five major aspects of the Nature of Science: definitions of science, scientific knowledge, the nature of scientific

knowledge, the development of scientific knowledge and the interrelations of science, technology, and society.

4.2.1 Definitions of Science

Before attending the program, as shown in Table 5.8, Ms. Jintana responded to items 1 and 2 of the NOSI questionnaire by agreeing with both traditional and contemporary views of the definitions of science. From this it could be inferred that she had a mixed or a blended view of the definition of science. She seemed to view science as both a body of knowledge and a process to understand the world with.

In the open-ended part of the questionnaire, Ms. Jintana said that the subject of science that it was related to natural things close to us and it can be perceived by our five natural senses.

In the semi-structured interview, Ms. Jintana was asked: *Based on the Nature of Science or science subject, what is the meaning or definition of science?* Her answer was:

Science is natural things which are surrounding us ... I will tell students and ask them what natural things are ... sometimes, they are things which were human made ... I will give an example ... by using things which students can see clearly and close to them (Ms. Jintana).

From the answer, she seemed to view science as body of knowledge to explain to her students. She seemed to define science education or give the definition of science from a teacher's perspective. She seemed to adopt a traditional view of science as a body of knowledge in her classroom teaching rather than a contemporary view of science as process.

For item 3, she agreed with the statement which stated that science is inventing and designing things and finding out ways to make people's lives better. From this it could be inferred that Ms. Jintana had an alternative conception of the differences between science and technology. She seemed to view science in terms of technology and she might have a utilitarian view which thinks that the aim of science is to help finding ways to make people's lives better.

In the first session of the program, there was a discussion about her personal view on science and teaching science. Ms. Jintana expressed her personal idea as being that science made us be thoughtful, critical, and creative. In the second session of the program, there was a discussion about what more the teachers knew about science and scientists after doing activities. Ms. Jintana mentioned that she learnt more about the scientific concept of balance.

After attending the program, Ms. Jintana responded to items 1 and 2 of the NOSI questionnaire by still agreeing with traditional view and strongly agreeing with contemporary view of the definitions of science. From this it could be inferred that she had a mixed or blended view of the definition of science. She seemed to view science as both a body of knowledge and a process to understand the world.

For item 3, she still agreed with the statement that science is inventing and designing things and finding ways to make people's lives better. This implies that Ms. Jintana had an alternative conception of the different definitions of science and technology. She seemed to view science in terms of technology and she might have a utilitarian view which thinks that the aim of science is to help find ways to make people's lives better.

4.2.2 Scientific Knowledge

(1) Source of Scientific Knowledge

Before attending the program, Ms. Jintana responded to questionnaire items 4 and 5 by agreeing with the traditional view of the source of scientific knowledge that scientific knowledge is discovered by scientists through observation and scientific method. She also agreed with the contemporary view of the source of scientific knowledge that scientific knowledge is generated by scientists through their process of thought, based on empirical evidence. Thus, Ms. Jintana seemed to have mixed traditional and contemporary views of the source of scientific knowledge.

In the semi-structured interview, Ms. Jintana was asked to explain where scientific knowledge comes from. From her teaching and learning perspective, Ms. Jintana thought that scientific knowledge came from studying existing knowledge by demonstration, observation, discussion, and analytical thinking. As she explained:

... I would bring students to the demonstration room ... There are demonstration pictures and models ... [and] bring students to the laboratory room ... I would let students observe ... [I would] give examples to students for they will think ... [I would] guide them to think by themselves ... [It should] emphasize thinking, analyzing, synthesizing ... (Ms. Jintana).

After attending the program, Ms. Jintana responded to questionnaire items 4 and 5 by still agreeing with the traditional view of the source of scientific knowledge that scientific knowledge is discovered by scientists through observation and scientific method. She also agreed with the contemporary view of the source of scientific knowledge that scientific knowledge is generated by scientists through their process of thought, based on empirical evidence. Thus, it could be

inferred that Ms. Jintana seemed to have a mixed traditional and contemporary view of the source of scientific knowledge.

(2) Nature of Scientific Knowledge

There are three sub-points to the nature of scientific knowledge focused on in this research.

i) Validity of Scientific Knowledge

Before attending the program, Ms. Jintana's response to a statement about the validity of scientific knowledge on the NOSI questionnaire is shown in item 6. She agreed with the contemporary view which emphasized that validity of scientific knowledge is based on both confirmation of empirical evidences through scientific method and experiments and approval of the scientific community.

After the program, it was found that she still agreed with the contemporary view which emphasized that the validity of scientific knowledge is based on both confirmation of empirical evidences through scientific method and experiments and approval of scientific community.

ii) Definitions of Different Kinds of Scientific Knowledge

Before attending the program, Ms. Jintana's responses to statements about different kinds of scientific knowledge on the NOSI questionnaire are shown in items 7 and 8. Ms. Jintana chose the neutral response to item 7. This could mean that she had a naïve understanding about the difference between using the words facts, concepts, principles, laws and theories in science and using these words in daily life. Ms. Jintana strongly agreed with item 8, from which could be inferred that she had alternative conceptions that scientific facts could be simply developed to become scientific theories which then turn into scientific laws.

In the semi-structured interview, Ms. Jintana was asked: *Have you heard about scientific terms including facts, concepts, principles, laws and theories before? In your understanding, what are they or what do they mean?*

When she was asked about these, she obviously accepted that she was confused about these scientific terms and had to study these because she did not major in science. She gave some explanations of these scientific terms from her understanding:

Theory and fact ... Theory is, I think, some laws which were established ... But truth is unchangeable ... and it is always true ... I feel, theory is established to be laws, to be some items and it is used as reference and supplement the truth ... I'm not sure whether it is correct or not (Ms. Jintana).

From Ms. Jintana's answer, she seemed confused between the words 'fact' and 'truth', using the word 'truth' in place of 'fact'. She seemed to confuse the characteristics and roles of theory, law, and fact.

In the fifth session of the program, there was a discussion to draw conclusions about the conceptions of the Nature of Science gained from doing experiments and reading articles. Ms. Jintana stated that there were various kinds of scientific knowledge.

After attending the program, Ms. Jintana still chose the neutral response to item 7 of NOSI questionnaire. This could mean that she had a naïve understanding about the difference between using the words facts, concepts, principles, laws and theories in science and using these words in our daily lives. Ms. Jintana still agreed with item 8, from which it could be inferred that she had an alternative conception that scientific facts could be simply developed to become scientific theories which then become scientific laws.

iii) Specific Characteristics of Scientific Knowledge

Before attending the program, Ms. Jintana's responses to statements about specific characteristics of scientific knowledge on the NOSI questionnaire are shown in items 9 to 11. Ms. Jintana disagreed with item 9 but agreed with items 10 and 11. From these responses, it could be inferred that Ms. Jintana had a contemporary view on the aspect which recognized that scientific knowledge is tentative and changeable. She had a traditional view which lacked concern for the subjective and perceptually bonded characteristics of scientific knowledge.

After attending the program, Ms. Jintana still made a neutral choice for item 9. From this it could be inferred that she neither agreed nor disagreed with the traditional view of science which showed the tentativeness of scientific knowledge. Ms. Jintana still disagreed with item 10. This implies that she agreed with the contemporary view which recognized the subjective and perceptually bonded characteristics of scientific knowledge. Ms. Jintana still agreed with item 11, which could imply that she agreed with the contemporary view which recognizes that science is changeable and empirically based.

4.2.3 Development of Scientific Knowledge

(1) Scientific World View and Basic Assumption of the Nature of Science

Before attending the program, Ms. Jintana's responses to statements about scientific world view and basic assumptions of the Nature of Science on the NOSI questionnaire are shown in items 12 to 16. As shown on Table 5.8, Ms. Jintana agreed with both item 12 and item 13. From this it could be inferred that she agreed with the contemporary view that the world could be understood by human intellect and its construction of reasonable explanations. She also agreed with the traditional view that the world and universe occur in consistent patterns and that we

could discover these patterns. Ms. Jintana strongly agreed with item 14, which means that she agreed with the traditional view which emphasized that science could provide absolute certainty or discover the truth of the natural world. For items 15 and 16, Ms. Jintana agreed to both of these items which could imply that she agreed with the contemporary view concerning science and scientific inquiry having inherent limitations.

After attending the program, Ms. Jintana still agreed with both item 12 and item 13. This could mean that she agreed with the contemporary view that the world could be understood by human intellect and its construction of reasonable explanations. She also agreed with the traditional view that the world and universe has consistent patterns which can be discovered. Ms. Jintana strongly still agreed with item 14, which means that she agreed with the traditional view which emphasizes that science could provide absolute certainty or discover the truth of the natural world. Ms. Jintana still chose neutral to item 15 and agreed with item 16. From this it could be inferred that she agreed with the contemporary view rather than the traditional view of the inherent limitations of science and scientific process.

(2) Scientific Method and Process

Before attending the program, Ms. Jintana's responses to statements about scientific method and process on the NOSI questionnaire are shown in items 17 and 18 of Table 5.8. Ms. Jintana disagreed with item 17. This means that she had a contemporary view which emphasizes that scientific method and process was theory-laden. She strongly agreed with item 18, from which it could be inferred that she agreed with the traditional view which emphasizes that scientific experiments or scientific method are the means to generate and verify truth in scientific knowledge as being true or false.

In the semi-structured interview, Ms. Jintana was asked to explain what scientific process was. She could not answer this question. She asked the interviewer to give examples for her. Then, she tried to give examples of her teaching

and learning activities but it did not draw out any scientific process. Thus, it could be inferred that she did not have a clear understanding about scientific process.

During the second session, there was a discussion about how teacher's problem-solving process of balancing a mobile with two different sizes and weights was similar to the scientists' process. Ms. Jintana commented on the importance of having principles and used those principles to solve problems.

While participating in the program, Ms. Jintana seemed to be interested in the discussion about some scientific process skills while designing and doing scientific experiments for free falling objects. In the third session, Ms. Jintana discussed controlling variables and repeating experiments in experimental design. In the fourth session, Ms. Jintana did experiment with controlled variables and repeated her experiments many times. In the fifth session of the program, there was a discussion to summarize conceptions of the Nature of Science gained from doing experiments and reading articles. Ms. Jintana mentioned that data gathering was a part of scientific process. It was found that when designing the lesson plan in session 12, Ms. Jintana liked to develop her students' science process and process skills in observation, exploration and classification.

After the program, Ms. Jintana wrote in her journal that she gained more understanding of scientific process. She learnt to use more logic in acquiring knowledge. She learnt that scientists did observation, research, exploration, and drew conclusions from their findings. She also learnt that after proving or doing experiments, there should be a conclusion, comparison, or decision made to accept or reject ideas.

After attending the program, Ms. Jintana's responses to the NOSI questionnaire showed that Ms. Jintana still agreed with item 17. This means that she had a traditional view which lacks concern that scientific method and process was theory-laden. She still agreed with item 18, from which it could be inferred that she agreed with the traditional view which emphasizes that scientific experiments or

scientific method are the means to generate and verify truth in scientific knowledge as being true or false.

(3) Characteristics of Scientific Inquiry

Before attending the program, Ms. Jintana's responses to statements about characteristics of scientific inquiry on the NOSI questionnaire are shown in items 19 to 22 of Table 4.4. Ms. Jintana's agreement with item 19 could mean that she agreed with the traditional view which considers that scientists use only a single scientific method, or fixed sets of orderly and logical steps, as tools for their research. For item 20, Ms. Jintana agreed with this item. This implies that she agreed with the contemporary view which held that science was an attempt to explain and predict phenomena as the most accurate reflection of reality with concern for its limitation to discover or reveal the absolute truth. Ms. Jintana agreed with item 21. This could mean that she agreed with the traditional view which lacks concern for the role of imagination and creativity in scientific inquiry. For item 22, Ms. Jintana agreed with this item, which implies that she agreed with the contemporary view which emphasizes the role of communication of scientific results in contributing to scientific inquiry. In the open-ended part of the questionnaire, Ms. Jintana mentioned some processes and skills that related to scientific inquiry including observation, questioning, working systematically.

From the semi-structured interview, it was found that Ms. Jintana seemed to emphasize logical-reasoning in scientific inquiry. As she said:

... I would bring students to survey the school grounds about the environment ... sometimes, students did work sheets to practice thinking ... to develop students analytical thinking ... every subject must have analytical thinking (Ms. Jintana).

In the seventh session, there was a discussion about how the good characteristics of science teaching approaches related to the Nature of Science.

Ms. Jintana commented that from learning by self study systematically, students would learn to solve problems rationally. By group work, students would learn to discuss knowledge together. Thus, it seemed that Ms. Jintana recognized the roles of logical-reasoning and communication in scientific inquiry.

After attending the program Ms. Jintana still agreed with item 19 of NOSI questionnaire which could mean that she agreed with the traditional view which considers that scientists use only a single scientific method, or fixed sets of orderly and logical steps, as tools for their research. For item 20, Ms. Jintana still agreed with this item. This could mean that she agreed with the contemporary view which holds that science is an attempt to explain and predict phenomena as the most accurate reflection of reality, but with a concern for its limitation to discover or reveal the absolute truth. Ms. Jintana still disagreed with item 21. This could mean that she agreed with a contemporary view which recognizes the role of imagination and creativity in scientific inquiry. For item 22, Ms. Jintana still chose neutral, from which it could be inferred that she neither agreed nor disagreed with the contemporary view which emphasizes the role of scientific results communication in contributing to scientific inquiry.

4.2.4 Interrelations between Science, Technology, and Society

For this major aspect, Ms. Jintana's understanding was investigated as a whole and as particular points, interrelation between science and technology, and interrelation between science and society.

For the whole aspect of interrelation between science, technology, and society, before attending the program, Ms. Jintana strongly agreed with item 25. From this it could be inferred that she agreed with the contemporary view of the interrelation between science, technology, and society.

After attending the program, Ms. Jintana still agreed with item 25. This could imply that she agreed with the contemporary view which is concerned with the interrelation between science, technology, and society.

For particular points, Ms. Dara's responses to the questionnaire are shown and discussed in two sub-topics: interrelation between science and technology, and between science and society.

(1) Interrelation between Science and Technology

Before attending the program, Ms. Jintana agreed with a statement about the interrelation between science and technology on the NOSI questionnaire in item 26. From this it could be inferred that she agreed with the contemporary view of the relationship between science and technology.

From the semi-structured interview, it was found that Ms. Jintana considered that science related to the use of technological instruments appropriately. As she said:

How [science] relates to technology. For example, in communication such as using telephone or electricity, [we] should teach ways to use them correctly such as how to turn on and turn off a radio and computer ... (Ms. Jintana).

During the sixth session of the program, there was a discussion about whether science or technology came first. Ms. Jintana expressed her view that science should come first but she could not give the reason. The facilitator raised the issue that we have used facilities which were the products of technology such as fire, stone weapons since before we had an understanding and explanation for them. Ms. Jintana responded to this issue that science and technology might have originated at the same time.

It was found from the interview after the program that Ms. Jintana was still unclear about the relationship between science and technology. She commented:

... Sometimes, we can not distinguish whether one is science or technology
... Or they were together. They support one another. Which one comes first?
I am still confused (Ms. Jintana).

After attending the program, Ms. Jintana agreed with a statement about the interrelation between science and technology on the NOSI questionnaire in item 26. From this it could be inferred that she still agreed with the contemporary view which concerns the relationship between science and technology.

(2) Interrelation between Science and Society

Before attending the program, Ms. Jintana's responses to statements about the interrelation between science and society on the NOSI questionnaire are shown in items 23, 24, and 27 to 29 of Table 5.8. Ms. Jintana disagreed with item 23. From this it could be inferred that she agreed with the contemporary view which considers that scientific enterprise is not isolated from society and recognizes that science is a social complex activity. Ms. Jintana's response as agreeing with item 24 showed that she had a contemporary view which considered that scientists and science are part of intellectual, social, and cultural traditions. From Ms. Jintana's strong disagreement with items 27 and 28 it could be inferred that she had a contemporary view that scientists could not work without ethical considerations and people from all cultures contribute to science. For item 29, Ms. Jintana agreed with this item, from which it could be inferred that she had a contemporary view concerning the historical aspect of science or the evolutionary and revolutionary characteristics of science.

From the semi-structured interview, it was found that Ms. Jintana considered that science was related to our daily life as she said that: “We have to face science because everyday it already interacts with our lives”.

After attending the program, Ms. Jintana still disagreed with item 23. From this it could be inferred that she agreed with the contemporary view which considered that scientific enterprise is not isolated from society and recognized that science is a socially complex activity. Ms. Jintana’s response as still agreed with item 24 showed that she had a contemporary view which considers that scientists and science are part of intellectual, social, and cultural traditions. From Ms. Jintana’s continued disagreement with item 27 and strong disagreement with 28 it could be inferred that she had contemporary views that scientists could not work free of ethical considerations and people from all cultures contribute to science. For item 29, Ms. Jintana still chose neutral, which could mean that she neither agreed nor disagreed with the contemporary view of a historical aspect of science or evolutionary and revolutionary characteristics of science.

4.2.5 Characteristics of Scientists and Scientific Attitudes

Before attending the program, in the open-ended part of the questionnaire, Ms. Jintana gave answers about the components of scientific attitudes (question number 4), including thoughtful, suspicious, creative, moral, orderly, cooperative, and expressive of ideas.

From the semi-structured interview, it was found that Ms. Jintana thought about scientist’s characteristics as being:

What do scientists’ think about? ... they should be thoughtful and critical ... sometimes, [scientists] do experiments, search for principles of truth, find out facts ... [scientists] should have reasons for why they construct some things (Ms. Jintana).

From the findings, it could be inferred that she understood the meaning of scientific attitudes or thought patterns. Her ideas about the components of scientific attitudes could be grouped into the five aspects of curiosity, reasoning, trustworthiness, circumspection, and broad-mindedness.

In the fifth and sixth sessions of the program, there was a discussion to summarize conceptions of the Nature of Science gained from doing experiments and reading articles. Ms. Jintana mentioned that scientists were investigative, imaginative, circumspect, and open-minded.

After the program, it was found from Ms. Jintana's journal that she learnt that scientists should be observant and search for data. They should repeat experiments before accepting results. They should not believe in anything easily without proof or doing experiments. Thus, Ms. Jintana seemed to recognize the characteristics of scientists or scientific attitudes in five aspects: curiosity, perseverance, reasoning, being circumspect, and broad-mindedness.

4.3 Teacher's Understanding of Instructional Approaches of the Nature of Science

In this section, data from interviewing, classroom observation, questionnaire responses and documents were gathered and analyzed to identify Ms. Jintana's understanding of instructional approaches related to the Nature of Science before and after attending the program. The findings are presented in two sub-topics; objectives of science teaching, and teaching approaches.

4.3.1 Objectives of science teaching

Before attending the program, Ms. Jintana stated in the questionnaire and interview responses that the objective of her science teaching was to develop students' understanding of the surrounding environment and awareness of values and uses of the natural environment for the most benefit. The important topic

in her science teaching was the environment. She emphasized developing students' skills in observing, questioning, orderly working, cooperating in groups, expressing ideas, and creative thinking. Students should be able to test things which they have observed in finding out facts. She also mentioned that students should practice to be observant, curious, rational, disciplinary, creative, and moral.

In the first session of the program, before starting training activities, in the open-ended part of the NOSI questionnaire Ms. Jintana was asked to write down the aims of her science teaching and learning with reasons. She stated that her science teaching was to develop students' understanding of natural things surrounding them. She aimed to teach students to be observant, have reasons, and be able to do experiments to find out facts.

During the program, in the first session, Ms. Jintana paid attention to the discussion about the 'best practice' teacher's aim to develop students to be scientists. However, she did not agree with the majority of the class. In the seventh session, Ms. Jintana joined in the discussion about the relationship between the aims of science teaching and teacher's views on science. She only expressed her aims of science teaching, which were to develop students' understanding of natural surrounding things and their ability to do systematic and orderly observation.

After the program, Ms. Jintana was asked to review her answers on the open-ended part of the NOSI questionnaire and she was asked, if she wanted, to rewrite her aims of science teaching and learning with reasons. Ms. Jintana added new aspects in her answers. She stated that there should be teaching and learning by using more process and rationale and by following all the steps of experimentation so students could have creativity and have a wider vision.

4.3.2 Teaching approaches

Before attending the program, Ms. Jintana considered that science teaching and learning activities should be set based on a student-centered approach.

Students should learn by self study and ask questions of the teacher and sometimes work in groups. She emphasized practicing students' rational thinking through her guided questioning. She thought that by these activities students would become thoughtful, curious, and brave in expression in a good way and have good attitudes toward the subject.

In her science teaching, she Ms. Jintana used questioning and classroom discussion as her main approach to teach about scientific facts and concepts. She also used individual and group work, presentations in front of the class, and exercises in work books. She also taught by integrating science with other subjects in some topics which had related or similar contents. It was found that instructional media and resources used in her teaching were pictures, student work books, drawing paper and crayons, other students, and some practical and simple things in the school grounds.

To assess students' learning of science, Ms. Jintana used questioning, observation performance while engaging in science class activities and presentation in front of the class, correcting student work and paper-pencil tests.

In the first session of the program, before starting training activities, in the open-ended part of the NOSI questionnaire Ms. Jintana was asked to write down her teaching approaches for the Nature of Science. She stated that students should have experience in exploring real things or reality such as studying plant growth from planting green beans.

During the program, in the fifth session, Ms. Jintana shared her ideas and experiences about how to develop students' understanding of the Nature of Science. She gave an example of letting students do simple experiments such as planting green bean, then observing and discussing applicable scientific concepts. When asked how she felt about doing inquiry activities in the previous session period, she said that it made her feel more curious. Ms. Jintana joined the discussion of students' learning of science and characteristics of good science teaching in the

seventh and eighth sessions. Ms. Jintana thought that students were eager and curious to solve problems in trials. Teachers should teach students by having them do exploration by themselves, systematic self study, or invention of toys so they would remember how to solve problems systematically. Teachers should use group work in teaching science so students could discuss their knowledge with each other. In the ninth session, there was a discussion about the necessity to inform to students of the concepts of the Nature of Science. Ms. Jintana stated that teachers might not tell about concepts of the Nature of Science directly but might use questioning. She accepted that she has never asked students about what they did similar to the way scientists do things. She thought that if she asked this question of her students, students might feel happy that they could also be scientists. She also thought that she would start to use this question with her students. In the tenth session, there was the activity of analyzing sample lesson plans and a discussion about how to develop student understanding of the Nature of Science. Ms. Jintana did not share any of her ideas in this discussion. She continued not to talk while Ms. Juntra and other teachers discussed these issues. In the twelfth session, it was found that Ms. Jintana's lesson plan stressed developing students' scientific concepts and science process skills including observation and classification.

After the program, Ms. Jintana was asked, if she wanted, to review her answer on the open-ended part of the NOSI questionnaire and to rewrite her teaching approaches for the Nature of Science. She wrote new answers. Her teaching approach for the Nature of Science was doing experiments to motivate students to be thoughtful, inventive, and eager for knowledge.

4.4 Teaching of the Nature of Science

Before attending the program, from classroom observation, Ms. Jintana's process of science teaching before attending the program could be summarized and illustrated in four sub-topics: classroom setting, introduction, teaching and learning activities, and conclusions.

4.4.1 Classroom setting

Ms. Jintana generally taught science in her classroom to approximately 30 students. She set students' desks in pairs and rows. The setting is illustrated in Figure 5.7 below.

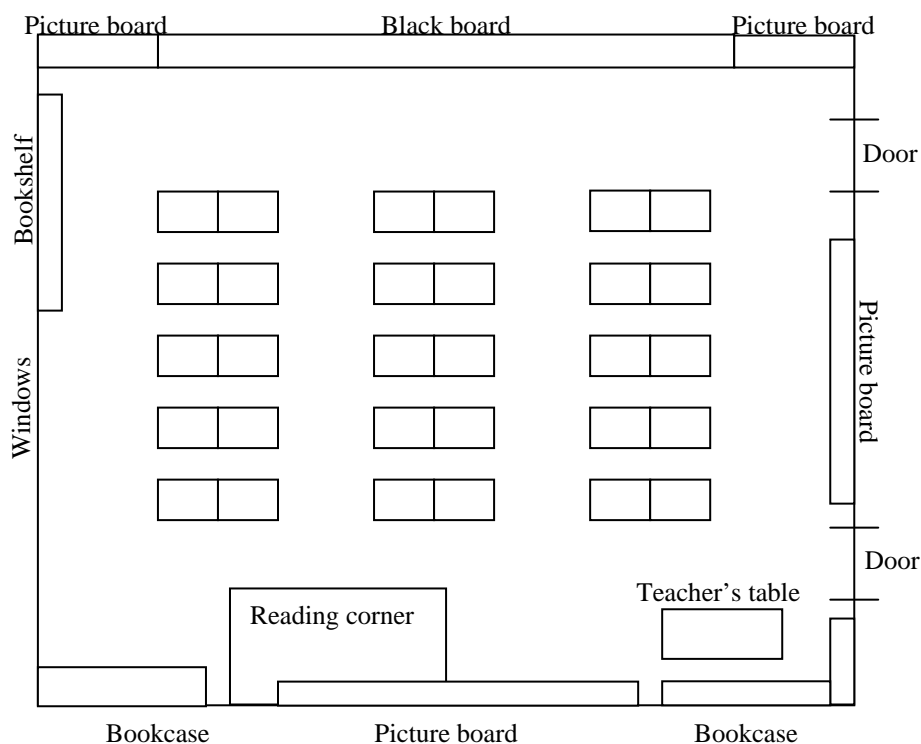


Figure 5.7 Ms. Jintana's Classroom Setting Before the Program

On the walls and the boards around the classroom, there were posters of pictures and learning information on the topics of mathematics, the human body, the environment, Thai alphabetic characters, and student work. There was a reading corner where students could spend their free time sitting on the floor and reading some interesting books.

4.4.2 Introductory

Ms. Jintana started the science class by giving students' science workbooks and telling students to study science in this period.

4.4.3 Teaching and learning activities

Ms. Jintana used students' science workbooks as teaching and learning media and resources with classroom discussion about the learning topic and concept. For example, she asked students to open workbooks and discuss the topic of living and non-living things. She asked her students to give some examples of living things and non-living things. Then, she led students in discussion about characteristics of living and non-living things. Finally, she talked about some additional knowledge such as plant breeding by humans and in nature.

4.4.4 Conclusion

Ms. Jintana used exercises in the student's science workbooks to ensure students understood the concept. For example, she asked students to do some exercises in classifying living and non-living things from the pictures in the workbooks. Firstly, she led students in reading instruction and she explained further. Then, she gave students time to do exercises. Finally, when students finished their exercises, each of them brought their workbook to Ms. Jintana. She checked and corrected the answers in the workbooks and gave feedback to each student.

After attending the program, from the interview after program, it was found that Ms. Jintana applied the explicit instructional approach for the Nature of Science in her science class. She used questions about what students did which was similar to scientists with her students. Ms. Jintana shared the experiences that she had when requiring students do experiments about the ability of three different kinds of soil (sandy, clay, and friable) to hold water. After doing the experiment she asked the students, 'Did you do the same as scientists?' and 'How similar were you to the scientists?' She found students could answer these questions. Students answered that they did experiments like scientists, found out data, and set questions. She also found that students liked to do experiments and they had good participation and collaboration.

Ms. Jintana found that students asked her curiously whether they could also be a scientist. She replied to her student that students were already being little scientists when they do experiments and set questions. She found the students could describe the components and steps of science process such as before doing the experiments, they should search for information. She also found that students sometimes built the toys, showed them to her, and asked if when they invent something they could be called scientists or not. She responded to her students by asking whether they did invent something, if so, they were already called scientists. She was impressed seeing her students being thoughtful, imaginative, and eager to do experiments. Students gathered unused objects and made toys by themselves. She thought that these kinds of questions were not difficult for students to answer and this was suitable with students in her level.

4.5 Factors' Affecting Teacher's Teaching of the Nature of Science

From the interview before program development and implementation, Ms. Jintana expressed her perceptions about factors affecting her science teaching in three major topics: readiness of students and classroom control, school and parental support, and teacher's load.

4.5.1 Readiness of students and classroom control

Ms. Jintana thought that she could not expect students to have high achievement in learning science because they were young. She thought that students could know and answer only about the surrounding environment close to them. They could not understand more complex concepts. She mentioned that students' lack of attention to learning and short concentration span affected her teaching. In her teaching, she had to use short lectures and design interesting learning activities for them.

4.5.2 School and parental support

Ms. Jintana considered that parents gave good support to her science teaching by giving funds for the teaching and learning materials for the school. Parents' supporting in developing students' direct experiences also promoted science teaching and learning. Ms. Jintana considered that students who had more direct experiences by going outside with their parents seemed to be able to understand the teacher's examples and explanations in science class rather than students who had less direct experiences.

For school support, Ms. Jintana thought that she could prepare simple teaching and learning media and resources by herself for the basic science contents. For teaching more complex science contents, she considered that the school had already supported these in the library provided, the computer room, laboratory room, and exhibition room.

4.5.3 Teacher's load

Ms. Jintana thought that the school gave a lot of extra work and documents for teachers to complete. For example, teachers had to work in each school's official units, to take turns to look after students both during and after school time, and to take turns to look after the school's cooperative store. Ms. Jintana thought that these extra jobs had affected her time to prepare the lessons.

4.6 Perspectives on the Program

From the interview after completion of the program, Ms. Jintana discussed her perspectives on what she had learnt from attending the program, the advantages of the program, and the disadvantages of the program. These perspectives are discussed below.

4.6.1 What the teacher had learnt from attending the program

It was found that what Ms. Jintana had learnt from the program could be divided into two major groups: conceptions of the Nature of Science, and teaching and learning approaches.

(1) Concepts of the Nature of Science

Ms. Jintana mentioned that when she attended the training program, it made her think back about the background of what she taught. She had never asked students about the Nature of Science. She found that when she talked about the Nature of Science with her students, students liked it and they were excited to be scientists. She found her teaching had developed and her students gained more understanding of science. She stated that she also developed her understanding of the Nature of Science from having interaction with her students during discussion about science and science process. She thought that what she has learnt from the training program was useful when she saw her students could answer the questions. Ms. Jintana mentioned that she would like to develop more understanding about analysis and synthesis thinking in science and about the relationship between technology and society and between science and technology. She also would like to have experience in doing more advanced scientific experiments.

(2) Teaching and learning approaches

Ms. Jintana had learnt more about teaching and learning approaches from the program on several issues. These issues are listed below.

- Appreciation in teaching concepts of the Nature of Science by discussion of what students did that was similar to scientists
- Appreciation in using scientific experiments in teaching science

4.6.2 Advantages of the program

Ms. Jintana expressed her opinion that this training program was good for having discussion and sharing ideas with peer teachers and facilitators. She thought that she gained more understanding and she was motivated to think more deeply and apply the questions to her students.

4.6.3 Disadvantages of the program

Ms. Jintana suggested that training content should emphasize various science subject matters. The training program should train teachers in developing teaching and learning materials and media. Ms. Jintana also mentioned that some questions used in the training program were hard to understand and needed to be clarified.

The Findings across Four Cases of Participant Teachers

The findings from the four cases were compared and analyzed across each theme and topic. According to cross case analysis, the findings are shown under four major topics; teacher understanding of the Nature of Science Instruction, teacher teaching of the Nature of Science, factors affecting their teaching of the Nature of Science, and teachers' perspectives on the training program.

1. Teacher Understanding of the Nature of Science Instruction

The findings of teachers' understanding of the Nature of Science instruction across four cases before and after the training program, were divided into two major sub-topics; understanding of concepts of the Nature of Science, and understanding of instructional approaches for the Nature of Science. These findings are shown as follows:

1.1 Understanding of conceptions of the Nature of Science

Before attending the program, all participant teachers, except Ms. Dara, had their views of the Nature of Science in between contemporary view and traditional view. Only Ms. Dara had contemporary view of the Nature of Science. Their understanding of each major aspects of the Nature of Science could be described in five sub-topics below.

After the program, it was found that Ms. Dara had a contemporary view of the Nature of Science while other teachers still had views of the Nature of Science in between contemporary and traditional. It was found from the mean score of all the questions that all participants' views of the Nature of Science, except Ms. Jintana's, had become more contemporary.

Participant teachers' understandings of each major aspects of the Nature of Science could be described in five sub-topics below.

1.1.1 Definitions of Science

Before attending the program, All participant teachers had views of the definition of science in between contemporary view and traditional view. They seemed to view science as both a body of knowledge and a process to understand the world. Three of them, except Ms. Jintana, seemed to appreciate the contemporary view of science as a process and adopt this view into their science instruction. Ms. Jintana seemed to appreciate the traditional view of science as a body of knowledge and adopt this view into her science instruction. For all participant teachers except Ms. Jintana, science related to the process of knowledge inquiry, scientific processes and process skills, thinking process, and application of knowledge to daily life. For, Ms. Jintana, science related to natural and sensible things that surrounded us and were close to us.

For the differences between science and technology, it was found that no participant teacher had an appropriate understanding. They seemed to view science in terms of technology and had a utilitarian view which that the aim of science was to help find ways to make people's lives better.

During the program, from the discussion about teacher's personal views on science and teaching science in the first session, it was found that Ms. Napar and Ms. Juntra viewed science as it related to the problem-solving process in daily life. Thus, they seemed to view science as a process. Ms. Dara viewed science as a subject to be taught and recognized the tentativeness of science and Ms. Jintana viewed science as it related to critical and creative thinking.

After the program, it was found that two participant teachers, Ms. Dara and Ms. Napar had contemporary view of the definitions of science. They viewed science as a process to understand the world. The other two participant teachers had views of the definitions of science in between contemporary and traditional views. They seemed to view science as both a body of knowledge and a process to understand the world. It was also found that Ms. Dara and Ms. Napar changed their views to become more contemporary in this aspect.

For the differences between science and technology, it was found that all participant teachers had less appropriate understandings. They seemed to view science in terms of technology and had a utilitarian view which that the aim of science is to help find ways to make people's lives better.

1.1.2 Scientific Knowledge

(1) Source of Scientific Knowledge

Before the program, it was found that Ms. Napar and Ms. Juntra had a more contemporary view of the source of scientific knowledge. This view considered that scientific knowledge is generated by scientists through their process

of thought based on empirical evidence rather than being simply discovered by scientists. Ms. Dara and Ms. Jintana had mixed traditional and contemporary views of the source of scientific knowledge which considered that scientific knowledge came from both discovery and generation by scientists.

During the program, it was found that Ms. Dara had developed more understanding in this aspect. Ms. Dara knew more about how scientists investigated scientific data from reading and analyzing articles in the second session. She also recognized that scientific knowledge came from an inquiry process and data gathering after doing inquiry activities from the third to the fifth sessions.

After the program, it was found that all participant teachers still had mixed traditional and contemporary views of the source of scientific knowledge which considered that scientific knowledge came from both discovery and generation by scientists. It was found that Ms. Dara and Ms. Juntra agreed more with the contemporary view of the source of scientific knowledge which emphasized scientific knowledge as being generated by scientists.

(2) Nature of Scientific Knowledge

i) Validity of Scientific Knowledge

Before the program, all participant teachers had a contemporary view of the validity of scientific knowledge. This view emphasizes that the validity of scientific knowledge is based on both confirmation of empirical evidences through scientific method and experiments and approval of the scientific community.

After the program, all participant teachers still had contemporary views of the validity of scientific knowledge. It was also found that Ms. Napar agreed more with contemporary view on this aspect.

ii) Definitions of Different Kinds of Scientific Knowledge

Before the program, all participant teachers had an inappropriate understanding of the difference between using the words facts, concepts, principles, laws and theories in science and using these words in daily lives. They also had an inappropriate understanding that scientific facts could be simply developed to become scientific theories which then turn into scientific laws. They could not clearly explain the terms, scientific theory, law, and fact.

After the program, all participant teachers, except Ms. Dara, still lacked understanding about the difference between using the words facts, concepts, principles, laws and theories in science and using these words in daily lives. All participant teachers still had an inappropriate understanding that scientific facts could be simply developed to become scientific theories which then become scientific laws. It was found that Ms. Napar and Ms. Juntra had a less appropriate view on this aspect.

iii) Specific Characteristics of Scientific Knowledge

Before the program, all participant teachers had contemporary views on the tentative and changeable characteristics of scientific knowledge. It was found that all participant teachers, except Ms. Dara, had no concern for the subjective and perceptual bonded characteristics of scientific knowledge.

After the program, all participant teachers had a contemporary view on the changeable and empirically based characteristics of scientific knowledge. Ms. Napar had a more contemporary view on this aspect. All participant teachers recognized the tentativeness of scientific knowledge, except Ms. Jintana who had mixed traditional and contemporary views in this aspect. It was found that all participant teachers except Ms. Jintana more lacked concern for subjective and perceptually bonded characteristics of scientific knowledge.

1.1.3 Development of Scientific Knowledge

(1) Scientific World View and Basic Assumption of the Nature

Before the program, all participant teachers, except Ms. Napar, had contemporary views that the world could be understood by human intellect and its construction could be explained reasonably. Only Ms. Napar had mixed traditional and contemporary views on this aspect.

It was found that only Ms. Juntra had a contemporary view of science which thought that the world could be understood by human intellect and its construction could be reasonably explained rather than just by discovering the existing patterns of nature. Ms. Dara and Ms. Napar had mixed traditional and contemporary views on this aspect. Ms. Jintana had traditional views on this aspect which emphasized the discovery of consistent patterns of nature.

Ms. Dara and Ms. Jintana had a traditional view which emphasized that science could provide absolute certainty or discover the truth of the natural world with no concern about its inherent limitations. Ms. Napar and Ms. Juntra had mixed traditional and contemporary views on this aspect. Only Ms. Jintana had a contemporary view which was concerned with the limitation of scientific inquiry, while Ms. Napar and Ms. Juntra had a mixed traditional and contemporary view, and Ms. Dara did not understand this.

After the program, all participant teachers had contemporary views that the world could be understood by human intellect and its construction has a reasonable explanation. Ms. Jintana had more a contemporary view on this aspect. All participant teachers had traditional views that the world and universe occurred in consistent patterns which we could discover. Ms. Dara had a more traditional view on this aspect. All participant teachers had traditional views which emphasized that science could provide absolute certainty or discover the truth of the natural world. Ms. Napar had a more traditional view on this aspect. All participant teachers, except Ms.

Napar, had contemporary views which were concerned with the limitations of science and scientific inquiry. Ms. Dara had a more contemporary view on this aspect. Ms. Napar had a traditional view on this aspect which lacked concern for the limitations of science and scientific inquiry.

(2) Scientific Method and Process

Before the program, it was found that all participant teachers except Ms. Juntra had a contemporary view which emphasizes that scientific method and process is theory-laden. Only Ms. Juntra had mixed traditional and contemporary views on this aspect. All participant teachers except Ms. Napar had the traditional view which emphasizes that scientific experiments or scientific method are the means to generate and verify truth in scientific knowledge as true or false. Only Ms. Napar had mixed traditional and contemporary views on this aspect. It also found that participant teachers could not clearly explain the components of scientific process.

During the program, all participant teachers seemed to develop more understanding of the scientific process and scientific process skills. They could name major components of scientific process. They could discuss the meaning of hypothesis, controlling of variables, repeating experiments, data recording, data manipulating, and making conclusions.

After the program, it was found that Ms. Dara and Ms. Napar had contemporary views which emphasize that scientific method and process are theory-laden. Ms. Juntra and Ms. Jintana had a traditional view on this aspect. All participant teachers had the traditional views which emphasized that scientific experiments or scientific method are the means to generate and verify truth in scientific knowledge as true or false. Ms. Napar had more traditional view on this aspect.

(3) Characteristics of Scientific Inquiry

Before the program, it was found that Ms. Dara and Ms. Jintana had traditional views which hold that scientists use only a single scientific method, or other sets of orderly and logical steps, as tools for their research. Ms. Napar and Ms. Juntra had a contemporary view on this aspect which believes that scientists do not use only a single scientific method, or fixed sets of orderly and logical steps, as tools for their research.

Ms. Dara and Ms. Jintana had contemporary views which emphasize that science is an attempt to explain and predict phenomena as the most accurate reflection of reality with a concern for its limitations in discovering or revealing the absolute truth. Ms. Juntra had mixed views on this aspect while Ms. Napar did not understand this.

It was found that Ms. Dara did not know about the processes of scientific experiments. The processes and skills related to scientific inquiry from participant teachers' ideas were composed of logical reasoning, questioning, observation, experimentation, researching, working systematically, and problem-solving.

During the program, all participant teachers seemed to develop more understanding of the characteristics of scientific inquiry. They could recognize that observation and scientific experiment were part of scientific inquiry. They recognized the roles of logical reasoning and communication in scientific inquiry.

After the program, it was found that Ms. Dara and Ms. Juntra had more contemporary views which recognize that scientists do not use only a single scientific method, or fixed sets of orderly and logical steps, as tools for their research. Ms. Napar and Ms. Jintana had traditional views of this aspect. Ms. Dara and Ms. Jintana had contemporary views which emphasize that science is an attempt to explain and predict phenomena as the most accurate reflection of reality with a

concern for its limitation to discover or reveal the absolute truth. Ms. Napar and Ms. Juntra had traditional views of this aspect. All teachers, except Ms. Juntra, had contemporary views on the role of imagination and creativity in scientific inquiry. Ms. Dara had a more contemporary view on this aspect. Ms. Juntra, had traditional view of this aspect. All participant teachers, except Ms. Jintana, had contemporary views which recognized that communication of scientific results contributed to scientific inquiry. Ms. Napar developed a contemporary view on this aspect from not understanding it before attending the program. Ms. Jinata had mixed traditional and contemporary views on this aspect.

1.1.4 Interrelation between Science, Technology, and Society

Before the program, all participant teachers, except Ms. Napar, had contemporary views in recognizing the interrelation between science, technology, and society. Only Ms. Napar had traditional view with a lack of recognition of the interrelation between science, technology, and society.

After the program, all participant teachers had contemporary views in recognizing the interrelation between science, technology, and society.

(1) Interrelation between Science and Technology

Before the program, Ms. Juntra and Ms. Jintana had contemporary views about the relationship between science and technology. Ms. Napar had mixed views from which it could be inferred that she was sure whether or not science and technology had a relationship with each other. Ms. Dara did not understand about the relationship between science and technology.

During the program, it was found that Ms. Dara firmly believed that science came before technology because she viewed science as a process to develop technological equipment. Ms. Jintana thought that science and technology

might have originated at the same time, but her understanding of the relationship between science and technology was unclear.

After the program, it was found that all participant teachers had contemporary views of the relationship between science and technology. Ms. Napar had a more contemporary view on this aspect.

(2) Interrelation between Science and Society

Before the program, it was found that all participant teachers, except Ms. Napar, had a contemporary view which holds that science is not separated from or in isolation from humanity. Ms. Napar had mixed traditional and contemporary views on this aspect.

Ms. Dara and Ms. Jintana had contemporary views which recognized the social and cultural contexts in which scientists worked and science as being part of intellectual, social, and cultural traditions. Ms. Juntra had mixed traditional and contemporary views on this aspect. Ms. Napar had a traditional view which lacked concern for social and cultural contexts of science and science as part of intellectual, social, and cultural traditions.

All participant teachers, except Ms. Napar, had a contemporary view which concerned itself with the social aspect of science in which science is a complex social activity. Only Ms. Napar had a traditional view which lacked concern in this aspect.

All participant teachers had contemporary views which appreciated that scientists could not work free of value and ethics. Ms. Dara and Ms. Jintana had a contemporary view which recognizes the historical aspect of science or the evolutionary and revolutionary characteristics of science while Ms. Juntra had mixed traditional and contemporary views on this aspect. Ms. Napar did not understand this.

After the program, it was found that Ms. Dara and Ms. Jintana had contemporary views that science is not separated or in isolation from humanity. Ms. Napar and Ms. Juntra had more traditional views on this aspect. All participant teachers had contemporary views which recognise the social and cultural context in which scientists worked and that science is part of intellectual, social, and cultural traditions. All participant teachers had contemporary views which are concerned about the social aspect of science in which science is a complex social activity. All participant teachers had contemporary views which appreciated that scientists could not work value- and ethics- free. All participant teachers, except Ms. Jintana, had contemporary views which recognize the historical aspect of science or the evolutionary and revolutionary characteristics of science. Ms. Napar and Ms. Juntana had more contemporary views on this aspect. Ms. Jintana had mixed traditional and contemporary views on this aspect.

1.1.5 Characteristics of Scientists and Scientific Attitudes

Before the program, only Ms. Jintana could clearly describe the components of scientific attitudes including curiosity, reasoning, trustworthy, circumspect, and broad-mindedness. Other participant teachers could not clearly describe these components of scientific attitudes although they seemed to appreciate some components in their science instructions such as reasoning, curiosity, and open-mindedness.

After the program, all participant teachers recognized the curiosity aspects of scientific attitudes. This aspect is that scientists must be suspicious, observant, eager to investigate, and inventive. All participants, except Ms. Dara, recognized the broad-minded aspects of scientific attitudes. Ms. Juntra and Ms. Jintana recognized the reasoning aspect of scientific attitudes. Only Ms. Jintana could recognize perseverance and circumspection aspects of scientific attitudes.

1.2 Understanding of instructional approaches for the Nature of Science

1.2.1 Objectives of science teaching

Before the program, it was found that all participant teachers had major objectives in science teaching to develop students' abilities in performing processes of knowledge inquiry including scientific processes and skills, in having critical thinking and reasoning, in solving problems systematically, and in the application of knowledge to daily life. For Ms. Jintana, the objectives were also focused on developing students' understanding of scientific concepts and scientific attitudes including curiosity, rationality, discipline, creativeness, and morality. Ms. Dara emphasized developing students' attitudes toward learning science. Ms. Napar emphasized developing students' awareness of the relationship between science, technology and environment. Ms. Juntra emphasized encouraging students to express their ideas and practice appropriately in learning science.

At the beginning of the program, it was found that there were six major aspects which participant teachers would have liked to develop in students. The first aspect was about developing students' ability to do investigation, classification, and experimentation (Ms. Napar, Ms. Juntra, Ms. Jintana). The second aspect was to develop problem-solving abilities (Ms. Dara, Ms. Juntra). The third aspect was to develop students' critical thinking and logical reasoning (Ms. Dara, Ms. Napar, Ms. Juntra). The fourth aspect was to apply and use science in daily living (Ms. Dara, Ms. Juntra). The fifth aspect was to develop students' knowledge in themselves and the environment (Ms. Napar, Ms. Juntra, Ms. Jintana). The last aspect was to develop some scientific attitudes including rationality, skepticism, observation, and eagerness to search for the truth (Ms. Juntra, Ms. Jintana).

During the program, all participant teachers seemed to realize that there was the relationship between the aims of science teaching and the teacher's views on science. Ms. Juntra gave an example that she thought that science was about

problem-solving. Thus, she aimed to teach students to be able to investigate or search for problematic truth.

After the program, it was found that all participant teachers extended or changed their objectives of science teaching. It was found that all participant teachers were concerned more about developing students' scientific attitudes and beliefs including observance and creativity. Teachers continued to develop students' ability in using scientific process in searching data, in doing investigation, and in daily life (Ms. Dara, Ms. Napar, Ms. Juntra). Teachers also continued to develop students' thinking and their reasoning ability (Ms. Dara, Ms. Juntra) and to develop the student's understanding of various kinds of knowledge (Ms. Juntra). There were new aspects of the objectives of science teaching added after the program. These objectives were to develop students' morals, ethics, and attitudes in using science and technology creatively and to develop students' abilities in imagination, communication, and decision-making (Ms. Dara).

1.2.2 Teaching approaches

Before the program, it was found that science teaching and learning activities were set based on science contents (Ms.Napar, Ms.Juntra) and based on ideas of student-centered approaches (Ms. Juntra, Ms.Jintana). Participant teachers also chose teaching and learning activities based on their intention to develop students' understanding of basic science processes and skills (all teachers), students' critical and rational thinking (Ms.Napar, Ms.Juntra, Ms.Jintana), students' problem-solving and application of knowledge (Ms. Napar). Their approaches for science teaching and learning were learning by process (Ms.Dara, Ms.Napar, Ms.Juntra), learning from various teaching and learning activities (Ms.Napar), learning by guided questioning from teachers (Ms.Jintana), learning from surrounding real things and settings (Ms.Dara, Ms.Napar, Ms.Juntra), and learning by self-study and group work (Ms.Napar, Ms.Juntra, Ms.Jintana). All participant teachers also mentioned that they taught science by integrating with other subjects in some topics which had related or similar contents.

Teaching techniques which were used in their science teaching were observing, classifying, and exploring surrounding things and the school grounds (Ms.Dara), questioning and classroom discussion (all teachers), students' presenting in front of the class (Ms.Dara, Ms.Jintana), doing exercises in worksheets and work books (all teachers), individual working and group working (all teachers), playing games (Ms. Napar), singing songs (Ms.Napar), and drawing pictures (Ms.Napar, Ms.Jintana). Teaching and learning media and resources used in their science teaching were pictures (all teachers), some practical and simple things from the school grounds and accompanying students (all teachers), drawing paper and crayon (Ms.Napar, Ms.Juntra, Ms. Jintana), and students' worksheets and workbooks (Ms.Dara, Ms.Juntra, Ms.Jintana).

All participant teachers used the same techniques to assess students' science learning. These were observation of students' performances while engaging in science class activities, correction of students' work, paper-pencil tests after completion of learning topic, and questioning and oral tests.

At the beginning of the program, it was found that all participant teachers thought that students should learn science from having direct experiences by themselves in doing scientific process, investigation, exploration, and experimentation. They should learn science with real surrounding things.

During the program, teachers maintained the same ideas expressed through the discussion of students' learning of science and the characteristics of good science teaching. Teachers also raised two other issues about science teaching approaches. The first was that teachers should consider students' interests and have demonstrations or experiments which were interesting and meaningful for students. The second issue was that teachers should use group work in science activities such as exploration. Students would learn to share and discuss knowledge with their peers.

In the discussion about how to develop students' understanding of the Nature of Science, it was found that Ms. Napar was the only person who did not share any ideas. All other participant teachers shared similar ideas about teaching

approaches for the Nature of Science. These approaches were the uses of practical activities including observation, investigation, experimentation, exploration, and classification. Ms. Juntra mentioned that after doing these activities, teachers should guide students in the discussion. This was so students could see whether or not they have a correct understanding of science from what they learn by themselves. Ms. Jintana also mentioned that teachers might not teach concepts of the Nature of Science directly but might use questioning. She agreed that the reflective questions such as asking what students did that was similar to scientists could possibly be applied to students in the science class. These questions would develop students' attitudes toward science. It was found that Ms. Dara appreciated that the article about scientists' experiments on free falling objects could motivate students' interest in doing scientific experiments.

After the program, it was found that Ms. Napar was the only person who did not change or add any new answers on the open-ended part of the NOSI questionnaire. For other teachers, there were different responses found among them. The teaching approaches Ms. Dara added to her answers were a coordination of all teaching approaches which were raised during the training program discussions. Ms. Juntra appreciated applying scientific process in teaching other subjects. Ms. Jintana emphasized using scientific experiments to develop students' thinking processes and scientific attitudes such as curiosity and inventiveness.

For the instructional approaches of the Nature of Science, it was found that all participant teachers appreciated the use of the practical activities of scientific process and scientific process skills in developing students' understanding of the Nature of Science. Three participant teachers, not including Ms. Juntra, appreciated asking reflective questions of students. However, only Ms. Jintana used these questions in her science class after attending the program. She found that students could describe the scientific process and they seemed to develop good attitudes toward science. Ms. Juntra thought that the discussion about the concepts of scientific process, scientific process skills, and characteristics of scientists after doing science activities was not suitable for Grade 1 students. These students were too

young to understand and participate in this type of discussion. So, she decided not to use this discussion with her students in science class.

2. Teacher Teaching of the Nature of Science

From cross cases analysis, participant teachers' process of science teaching before and after attending the program are summarized and illustrated in four sub-topics as follows.

2.1 Classroom setting

Before the program, all participant teachers had about 30-35 students per classroom. Only Ms. Dara set students' desks in a group of 4-5 students. Other participant teachers set students' desks in rows of pairs and single. There were posters of pictures and learning information related to science on the walls and boards around each classroom. There was also a reading corner in each classroom, except Ms. Juntra's.

After the program, it was found that all participant teachers, except Ms. Jintana, taught in the same grade and same room as in the 2004 academic year. Thus, their classroom setting and approximate number of students in their class were the same as the previous academic year. Ms. Dara set students's desks in rows of two students but she had students do science activities in groups by using free space on the floor at the back of the room. Ms. Napar and Ms. Juntra set students' desks in groups of six to eight students.

2.2 Introductory

Before the program, participant teachers started the science class by motivating students' interests in a learning science topic (except Ms. Jintana). They used classroom discussion with some learning media such as pictures, songs, or a

story in the student workbook. The discussion was focused on students' prior knowledge and experiences related to the learning topics.

After the program, Ms. Dara started the science class by setting students in groups and gave them worksheets to read and prepare for practical activities following the instruction. Ms. Napar and Ms. Juntra started the science class by motivating students' interests in the learning science topic. They used classroom discussion. The discussion was focused on students' prior knowledge and experiences relating to the learning topics.

2.3 Teaching and learning activities

Before the program, teaching and learning activities used by participant teachers were composed of classroom discussion on a learning topic and concept with teacher's guided questioning (all teachers), explanation and lecturing of the learning contents and concepts (Ms. Napar, Ms. Jintana), completing worksheets and workbooks to practice some understanding of concepts and some basic skills such as observation and classification (Ms. Dara Ms. Jintana), playing games to ensure students' understanding (Ms. Napar), working in groups (Ms. Dara), and students' presenting in front of the class (Ms. Dara).

After the program, teaching and learning activities used by participant teachers were composed of group work (all teachers), exploration and observation following teachers' instruction (all teachers), data recording (Ms. Dara), group discussion for drawing conclusions from the findings (Ms. Dara), demonstration (Ms. Napar), classroom discussion on the findings and learning concepts with teacher's guided questioning (all teachers), students' presentation of findings and conclusion in front of the class (Ms. Dara).

2.4 Conclusion

Before the program, at the conclusion of the lesson, participant teachers used classroom discussion to conclude learning concepts (Ms. Dara, Ms. Juntra). To ensure students' understanding of the concepts they had students complete worksheets and workbooks individually (Ms. Dara, Ms. Jintana) and drawing pictures (Ms. Napar, Ms. Juntra).

After the program, at the conclusion of the lesson, participant teachers used classroom discussion to conclude learning concepts (all teachers). To ensure students' understanding of the concepts they had students complete worksheets individually (Ms. Napar) and draw a concept map with text book reading (Ms. Juntra).

3. Factors Affecting Their Teaching of the Nature of Science

From all participant teachers' perspectives, there were four factors affecting their teaching of the Nature of Science. These factors were readiness of the students and classroom control; school and parental support, teaching experiences and skills and teacher's load.

3.1 Readiness of students and classroom control

Students lacked attention in studying and had short concentration spans (Ms. Napar, Ms. Jintana). Students worked slowly (Ms. Napar) and lacked ability in reading (Ms. Juntra). They were young and disorderly when doing practical activities (Ms. Dara). They could know and answer about the environment around about them, but could not understand more complex concepts (Ms. Jintana). Teachers had to be patient, help students in reading, wait for them to finish their work, and set interesting, creative, and flexible teaching and learning activities for them.

3.2 School and parental support

Parents gave good support to their teaching by preparing learning materials for their children to bring to school (Ms .Dara) and funding for the school's teaching and learning materials (Ms. Jintana). Teachers also thought that parental support in taking their children outside and letting them gain direct experience could promote students' science learning. Students who had more direct experiences were more likely to be interested in learning science and would learn faster (Ms. Dara), to discuss and express their ideas in science (Ms. Juntra), and to understand the teacher's explanations and examples (Ms. Jintana).

For school support, teachers thought that the school had already supported their teaching by providing a library, a computer room, a laboratory, and an exhibition room (Ms. Jintana). They also thought that the science contents in their teaching levels were not complex and they could prepare their own simple media and resources for their teaching and learning activities (Ms. Dara).

3.3 Teaching experiences and skills

The teachers' lack of knowledge and experience seemed to result in a lack of ability in teaching scientific process (Ms. Napar).

3.4 Teacher's load

The extra responsibilities in the school such as teacher meetings, school documents to complete, school activities had affected teachers in preparing their lessons and activities (Ms. Dara, Ms. Jintana).

4. Teacher Perspectives on the Program

From the interviews after the program, all participant teachers had views about what they learnt from attending the program, the advantages and the disadvantages of the program. These views are discussed below.

4.1 What teachers had learnt from attending the program

It was found that what all participant teachers had learnt from the program could be divided into two major groups: concepts of the Nature of Science, and teaching and learning approaches.

4.1.1 Concepts of the Nature of Science

Ms. Dara and Ms. Juntra already had some conceptions of the Nature of Science before attending the program. Ms. Napar and Ms. Jintana had never explicitly thought and taught students about the Nature of Science before attending the program. After attending the program, Ms. Dara and Ms. Juntra thought that they gained more understanding of the Nature of Science. Three participant teachers, except Ms. Dara, thought that they had known about the background of science and the source of science content which they taught and it was different from science content in the text books. It was found that this training program developed Ms. Jintana's scientific attitudes and Ms. Napar's attitudes toward teaching science. This training program gave Ms. Napar and Ms. Dara the guidelines to develop their ability in science teaching, their conceptions of the Nature of Science, and their attitudes toward teaching science. This training program could motivate Ms. Dara and Ms. Jintana's willingness to develop their understanding of the Nature of Science.

4.1.2 Teaching and learning approaches

All participant teachers had learnt more from the program in various issues of teaching and learning approaches which are summarized and listed below.

- Appreciation to apply scientific process and process skills in science teaching (All teachers)

- Knowing more about scientific inquiry, questioning, hypothesizing, and data recording which could apply to science teaching (Ms. Dara, Ms. Napar)

- Appreciation to teach concepts of the Nature of Science explicitly by using reflective questions or indicate scientists' biographies to develop students' conception of the Nature of Science, scientific attitudes, and attitude toward science (Ms. Dara, Ms. Napar, Ms. Jintana)

- Appreciation to apply scientific process and critical discussion in teaching Mathematics and Thai language

- Knowing more about how to use group work in science classes

- Appreciation in using classroom presentations

4.2 Advantages of the program

Ms. Dara and Ms. Napar thought that the training activities were interesting and fun and they could be applied in teaching. Ms. Juntra and Ms. Jintana thought that the training activities motivated them in thinking deeper all the time by questions which could be applied to students. All participant teachers had positive thoughts with discussion, sharing and presentation activities both individually and in groups. It was found that the small number of participants and all participants already knowing one another seemed to be positive factors for this training program. Ms. Napar thought that the training program was good to have for practical activities for teachers and to be set in school.

4.3 Disadvantages of the program

One major disadvantage of the training program was the time setting after school. All participant teachers, except Ms. Jintana, thought that after school was not suitable and limited. They suggested that the training program should be held in holidays or before or during semester break. The program should use more continuous periods of time such as a half day, a whole day or two to five days. Ms. Juntra and Ms. Jintana suggested the program content was too broad. They would like to learn

from training content which emphasized various science subject matters, specific scientific concepts, and specific scientific process skills. They also suggested that some wording and questions used in the training program were unclear and hard to understand. They needed to be clarified. It was found that the training for using scientific equipment, training for developing science teaching and learning materials and media, and outdoor training activities would be interesting for participant teachers.

Summary

From the study of participant teachers' understanding and teaching of the Nature of Science, the findings from the first phase of the research can be summarized and listed in several points listed below.

1. Before attending the program, participant teachers, on the whole, had contemporary views of science or a view in between traditional and contemporary views of science.

2. Before attending the program, participant teachers had many traditional views and inappropriate views in many particular concepts of the Nature of Science. These were the alternative concepts of the different definitions of science and technology; lack of understanding of definitions of the terms, roles and functions of scientific terms such as theory, law, and fact; lack of concern for the subjective and perceptually bounded characteristics of scientific knowledge; lack of understanding of the inherent limitation of scientific inquiry; a view of science that it could provide absolute certainty or discover the truth and discover consistent patterns of the universe; a view of scientific method and process as the means to generate and verify truth; a view that scientists used only a single scientific method or other sets of orderly and logical steps as tools for their research; lack of consideration of the role of imagination and creativity in scientific inquiry; lack of understanding of the role of communication of scientific results; lack of understanding of the components of scientific processes and experiments; lack of understanding of the relationship

between science and technology; lack of concern for the social and cultural context in which scientists worked and science as being a part of intellectual, social, and cultural traditions; lack of understanding of historical aspects of science or evolutionary and revolutionary characteristics of science; and lack of understanding of components of scientific attitudes.

3. Participant teachers lacked recognition and appreciation of the importance of understanding of the Nature of Science as a cognitive learning outcome to be explicitly taught and assessed in science classes.

From the study of participant teachers' teaching of the Nature of Science in the first phase of the research before attending the training program, the findings can be summarized and listed as follow.

1. Although lower primary school teachers in these cases wanted to develop students' abilities to do scientific process and have science process skills and problem-solving skills, they did not practically teach students about these. They seemed to emphasize teaching scientific concepts.

2. There was no explicit teaching of the concepts of the Nature of Science or explicit modelling behaviour that reflected appropriate understandings of the concepts of the Nature of Science, science processes and process skills.

3. The possible negative factors affecting their teaching were lack of science teaching experiences and skills, perceptions of students' readiness and classroom controlling, and teacher workloads. These factors generally affected participant teachers' preparation of science lessons and their science teaching.

From the study of the effects of an in-service primary school teacher professional development program on instruction of the Nature of Science on teachers' understanding and teaching of the Nature of Science in the third phase of the research, the findings can be listed as follows.

1. After attending the program, participant teachers, on the whole, had a more contemporary view of science.

2. Each participant teacher developed a more contemporary view of some specific aspects of the Nature of Science including definitions of science; the source of scientific knowledge; validity of scientific knowledge; the changeable and empirically based characteristics of scientific knowledge; scientific world view and basic assumption of the nature of science; limitations of science and scientific inquiry; scientific method and process; the role of imagination and creativity in scientific inquiry; the role of communication of scientific results; and the historical aspect of science.

3. Each participant teacher had developed more traditional and inappropriate views in some specific aspects of the Nature of Science including roles and functions of scientific terms such as theory, law, and fact; subjective and perceptually bonded characteristics of scientific knowledge; scientific world view and basic assumption of nature; limitations of science and scientific inquiry; and the social and cultural context in which scientists worked.

4. During and after attending the program, participant teachers recognized the relationship between the aims of science teaching and teacher's views on science. They seemed to more fully realize the importance of the Nature of Science in their science teaching.

5. After attending the program, all participant teachers extended or changed their objectives of science teaching to become more related to scientific process and process skills. Some objectives of science teaching related to the Nature of Science were newly added.

6. It was found that teachers continued to appreciate the uses of practical activities. Most of the participant teachers appreciated the use of explicit instructional approaches of the Nature of Science in their science teaching. They appreciated that

reflective questioning and indicating scientists' biographies might help improve students' conception of the Nature of Science, scientific attitudes, and attitude toward science.

7. After attending the program, some participant teachers viewed science as a method of enquiry which was powerful and generally able to be used in a range of other contexts, both scientific and non-scientific. They appreciated applying scientific process and critical discussion in teaching Mathematics and Thai language.

8. After attending the program, participant teachers used more practical activities related to science inquiry in their science teaching.

9. The possible factors which had negative effects on participant teachers' teaching of the Nature of Science were teachers' level of experience in science teaching, perceptions of students and judgment about students' developmental readiness, science content-specific knowledge, science self-efficacy; and the realities of classroom constraints; and teachers' teaching load.

10. It was found that during and after attending the program some participant teachers applied some modelled activities and training material to their science classes. Teachers taught their students the same aspects of the Nature of Science as modelled within the training program. They seemed to gain more appreciation on teaching the Nature of Science to their science class after they had received positive feedback from their students.

The discussion on the findings of all research phases and the discussion of the effects of the training program on the development of teachers' understanding and teaching of the Nature of Science will be presented in the next chapter.

CHAPTER VI

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents the discussion of the research findings from the first and the third phase of the research which was shown in Chapter Five. This is for answering the research questions and reaching the conclusions of this research study on four lower primary school teachers' understanding and teaching of the Nature of Science. There is also a discussion and conclusions of the effects of an in-service primary school teacher professional development program on instruction of the Nature of Science on the development of teacher's understanding and teaching of the Nature of Science.

In the first section of this chapter, there is an extensive discussion of the findings from the first phase of the research: probing teachers' understanding and teaching of the Nature of Science before attending the training program. The second section has the discussion of the effects of the training program on participant teacher's understanding and teaching of the Nature of Science. Then, there are the sections of conclusions from the findings, suggestions for program improvement, and recommendations for further research.

Discussion on Findings from Probing Teachers' Understanding and Teaching of The Nature of Science before Attending the Training Program

1. Teachers' Understanding of the Concepts of the Nature of Science

According to the theoretical scheme of generally agreed characteristics for the Nature of Science instruction (Chapter Two, section 2.6.1), teachers are required to have a contemporary rather than a traditional view of science. It was found that, in all of five major aspects of the Nature of Science, all participant teachers, except Ms. Dara whose view was contemporary, had an understanding somewhere between the

traditional and the contemporary views of science. Thus, these participant teachers still needed to increase their understanding of the Nature of Science towards having a more contemporary view. These findings were similar to the findings of many teachers' conceptions found in other research.

This finding correlated with Pomeroy's (1993) study and conclusion which reported that among scientists, secondary science teachers, and elementary teachers, elementary teachers held the most appropriate views of the Nature of Science, holding a less traditional and a more non-traditional, contemporary view of science. Pomeroy (1993) suggested that elementary teachers may have developed their alternative views of science from their views about children's learning, their own personal practice of teaching and construction of knowledge, and participation in in-service workshops emphasizing a constructivist approach to science.

This research found that all participant teachers had views of the definitions of science in between a contemporary view and a traditional view. They seemed to view science as both a body of knowledge and a process to understand the world. The finding of this research was congruent with the findings of Abell and Smith (1994) and Gess-Newsome (2002). They found that teachers could have combined views on the definition of science.

Participant teachers in this research had alternative conceptions of the differences between science and technology. They lacked an understanding of the relationship between science and technology. They viewed science as inventing and designing things and finding out ways to make people's lives better. They seemed to view science in terms of technology. The findings of this study are similar to other research which has found that most teachers did not distinguish between science and technology (Rubba and Harkness, 1993; Eick, 2000). Teachers in this study had a utilitarian view of science similar to many pre-service and in-service science teachers who thought that the aim of science was to help find ways to make people's lives better (Tairab, 2001).

Participant teachers in this research lacked an understanding of the definition of terms and the roles and functions of scientific terms such as theory, law, and fact. It was found that most of them had only simplistic views of the nature of scientific knowledge. This finding was similar to the findings with many teachers from the research of Rubba and Harkness (1993), Akerson, Abd-El-Khalick and Lederman (2000), and Eick (2000).

In this research, participant teachers lacked a concern for subjective and perceptual bonded characteristics of the scientific knowledge. This was similar to Murcia and Schibeci's findings (1999) that some teachers believed that observations could be made objectively and value-free.

All participant teachers of this research had contemporary views on the tentative and changeable characteristics of scientific knowledge but most of them lacked concern for the inherent limitations of scientific inquiry. They viewed science as being able to provide absolute certainty or discover the truth and discover consistent patterns of the universe and viewed scientific method and process as the means to generate and verify truth. They also viewed scientists as using only a single scientific method or other sets of orderly and logical steps as tools for their research. They lacked a concern for the social and cultural context in which scientists worked and science as being part of intellectual, social, and cultural traditions. They lacked understanding of the historical aspect of science or evolutionary and revolutionary characteristics of science. Most teachers seemed to lack an awareness of the roles of imaginative thought. These findings correlated with the findings from many research studies (Rampal, 1992; Rubba and Harkness, 1993; Abell and Smith, 1994; Tobin and McRobbie, 1997; Fysh and Lucas, 1998; Murcia and Schibeci, 1999; Akerson *et al.*, 2000). Participant teachers in this research lacked a concern for the role of imagination and creativity in scientific inquiry. This resembled to the research findings of Lakin and Wellington (1994) and Pomeroy (1993) that most teachers seemed to lack an awareness of the roles of imaginative thought in the scientific method.

Participant teachers in this research lacked understanding of components of scientific process and experiment. This finding was similar to the findings of Rubba and Harkness (1993), Murcia and Schibeci (1999), and Eick (2000). They found that most teachers could give only a simplistic description of possible methods of data collection and emphasized observation, explanation, and experimentation as crucial parts of the scientific process.

Participant teachers in this research lacked an understanding of the role of communication of scientific results. This was similar to many teachers who did not realize the role of the scientific community in communicating or debating competing theories (Abell and Smith, 1994).

In this research, all participant teachers had a contemporary view which appreciated that scientists' work could not be value- and ethics-free. This was different from many teachers who viewed scientists' work as value- and ethics- free (Murcia and Schibeci, 1999).

2. Teachers' Understanding of the Instructional Approaches of the Nature of Science

According to the theoretical scheme of generally agreed characteristics for the Nature of Science instruction (Chapter 2, section 2.6.1), teachers are required to appreciate the understanding of the Nature of Science as a cognitive instructional outcome (Lederman, 1998). They are also required to plan and consider concepts of the Nature of Science during the development of every instructional unit, lesson, and activity and explicitly teach and assess them during the implementation (Lederman, 1998; 1999). Teachers should set science teaching and learning activities and curriculum materials to ensure that students have several experiences when they are doing science, and then reflect on the process and what it implies about the Nature of Science. Teachers should also integrate a variety of formative assessments to continually monitor students' conceptions of significant issues in the Nature of Science (Clough, 1997).

It was found that all participant teachers in this research seemed to appreciate promoting students' scientific process and process skills, rational thinking, problem-solving skills, and application of knowledge to daily life. Some teachers appreciated developing students' understanding of the relationship between science, technology and society and develop scientific attitudes. Teachers had the intention to set teaching and learning activities according to these objectives. Their approaches to science teaching and learning were learning by basic scientific processes such as observation and exploration, learning from various teaching and learning activities, learning by guided questioning from teachers, learning from surrounding real things and settings, and learning by self-study and group work. These objectives and teaching approaches seemed to relate to participant teachers' conceptions of the Nature of Science as they viewed scientific inquiry related to observation, questioning, researching, experimentation, thinking and logical reasoning, problem solving, and working systematically.

However, participant teachers in this research seemed not to recognize and appreciate the understanding of the Nature of Science as a cognitive learning outcome to be explicitly taught and assessed in science classes. Their science teaching and learning activities focused on enhancing students' experiences in doing science with rational thinking about scientific concepts. Thus, the concepts of the Nature of Science seem to be embedded and conveyed implicitly within these participant teachers' instruction. Their approaches for science teaching and learning were learning by basic scientific processes such as observation and exploration, learning from various teaching and learning activities, learning by guided questioning from teachers, learning from real surrounding things and settings, and learning by self-study and group work. Participant teachers in this research seemed to think that by using these approaches students would simply come to understand the Nature of Science or scientific inquiry.

This kind of instruction could be referred as the implicit approach for teaching the Nature of Science. There were many teachers and science educators employing this instruction in their science teaching (Lederman and Abd-El-Khalick, 1998). The

findings of this research were similar to the findings of Akerson and Abd-El-Khalick (2003) who conducted a case study with one fourth grade teacher. They found that even though the teacher in their case study had informed views of the Nature of Science, she thought that she taught the Nature of Science by engaging students in doing activities and processes similar to what scientists did.

3. Teachers' Teaching of the Nature of Science and Affective Factors

According to the theoretical scheme of generally agreed characteristics for the Nature of Science instruction, teachers are required to model behaviors, strategies, and language that reflect appropriate understandings of the Nature of Science to their students; address explicit and implicit views of the Nature of Science portrayed in science activities; and set curriculum materials which adequately portrayed the Nature of Science (Clough, 1997).

From all the participant teachers' classroom settings in this research, no explicitly portrayed concepts of the Nature of Science were found. Participant teachers' teaching and learning activities emphasized developing students' understanding of scientific concepts through classroom discussion. From observation of science classes, none of the participant teachers' explicitly addressed the concepts of the Nature of Science or explicitly modelled behavior that reflected appropriate understanding of the concepts of the Nature of Science, science processes or process skills. It was found that all participant teachers in this research taught science by using classroom discussion on a learning topic and concept with teacher's guided questioning, explanation and lecturing of the contents and concepts of the subject, doing worksheets and workbooks to ensure understanding of concepts, playing games to ensure students' understanding, working in groups, and students' presenting to the class. Curriculum materials such as students' worksheets and workbooks were used to emphasize and develop students' scientific concepts rather than science process and process skills and concepts of the Nature of Science. Thus, it seemed that although teachers appreciated developing students' abilities in doing scientific process and have science process skills and problem-solving skills, they did not teach students

about these in a practical way. They seemed to emphasize teaching scientific concepts.

The lack of explicit teaching of the Nature of Science, science processes and process skills could possibly result from teachers not having the intention to teach concepts of the Nature of Science explicitly. Participant teachers in this research could possibly have also received negative influences from various factors such as teachers' lack of science teaching experiences and skills, teachers' perceptions of students' readiness and classroom control, and teacher loads. These factors generally affected participant teachers' preparation of science lessons and their science teaching. There were numbers of research studies which found similar factors influencing teachers' translation of their understanding of the Nature of Science into classroom practice (Lederman, 1999; Schwartz and Lederman, 2002; Akerson and Abd-El-Khalick, 2003; Hipkins, Barkers and Bolstad, 2004).

Discussion on Effectiveness of an In-Service Primary School Teacher Professional Development Program on Instruction of the Nature of Science

1. Effects of the Program on Teachers' Conceptions of the Nature of Science

Many research studies found that teachers' conceptions of the Nature of Science could be improved by engaging an explicit approach for teaching the Nature of Science in the teacher development program (Abd-El-Khalick and Lederman, 2000). From the findings of this research in Chapter Five, the mean score of all the questions showed that all participant teachers, except Ms. Jintana, developed a more contemporary view of the Nature of Science after attending the training program.

Also, each of participant teachers in this research improved to a more contemporary view on some specific concepts of the Nature of Science in all five major aspects. For the definitions of Science, Ms. Dara and Ms. Napar improved their views to become more contemporary. They appreciated more that science was a process to understand the world. Ms. Dara and Ms. Juntra agreed more with the

contemporary view of the source of scientific knowledge which emphasized that scientific knowledge was generated by scientists. Ms. Napar agreed more with the contemporary view of the validity of scientific knowledge and the contemporary view on the changeable and empirically based characteristics of scientific knowledge. Ms. Jintana had more of a contemporary view that the world could be understood by human intellect and its construction of reasonable explanations. Ms. Dara had a more contemporary view concerning the limitations of science and scientific inquiry on this aspect. Ms. Dara and Ms. Juntra had a more contemporary view which recognized that scientists did not use only a single scientific method, or fixed sets of orderly and logical steps, as tools for their research. Ms. Dara had a more contemporary view on the role of imagination and creativity in scientific inquiry. Ms. Napar developed a contemporary view which recognized that communication of scientific results contributed to scientific inquiry. She improved this view from ‘not understanding’ before attending the program. Ms. Napar and Ms. Juntana had a more contemporary view which recognized the historical aspect of science or the evolutionary and revolutionary characteristics of science. Thus, these findings indicated that the explicit approach for the teaching the Nature of Science could develop teachers’ conceptions of the Nature of Science.

It was found that each participant teacher in this research had developed more traditional and inappropriate views in some specific concepts of the Nature of Science. Ms. Napar and Ms. Juntra had a more inappropriate view that scientific facts could be simply developed to become scientific theories which then, in turn become scientific laws. Ms. Jintana lacked more understanding of the subjective and perceptually bonded characteristics of scientific knowledge. Ms. Dara had a more traditional view which emphasized that the world and universe occurred in consistent patterns which could be discovered. Ms. Napar had a more traditional view which emphasized that science could provide absolute certainty or discover the truth of the natural world. Ms. Napar had a more traditional view which emphasized that scientific experiments or scientific method are the means to generate and verify truth in scientific knowledge as true or false. Ms. Napar and Ms. Juntra had a more

traditional view which emphasized that science was separated or in isolation from humanity.

All of the concepts which participant teachers in this research had less appropriate understanding were not explicitly emphasized and discussed during the training program. Teachers might somehow develop these personal conceptions from engaging in inquiry activities or discussions in the training program. Matthews (1997) suggested that there were generally two opposite views of any serious intellectual or epistemological questions or issues about the Nature of Science. Thus, teachers might not always construct only contemporary views of the Nature of Science from engaging in doing science or inquiry activities.

While implementing the program, the researcher was aware that the purpose of teaching and learning about the Nature of Science in this training program should not be focused on transmitting facilitator's views of any aspects of the Nature of Science to make participant teachers agree with them and think as the facilitator thinks, but to have participant teachers think, understand, and become interested in aspects of the Nature of Science (Matthews, 1997). Thus, the researcher as a facilitator was open to any ideas which the participant teachers might raise in discussion about the concepts of the Nature of Science. It was found that after the program some participant teachers in this research had intentions to further develop their understanding on some aspects of the Nature of Science such as scientific process and the relationships between technology and society and between science and technology. This research study made similar findings to Akerson and Abd-El-Khalick's findings (2003) that the discourse and exchange of ideas with trusted and friendly colleagues could encourage teachers to externalize their conceptions of the Nature of Science.

2. Effects of the Program on Teachers' Understanding of the Instructional Approaches for the Nature of Science

To develop teachers' understanding of the instructional approaches for the Nature of Science, one intention of the training program was to enhance teachers'

appreciation of the importance of the Nature of Science as an instructional cognitive learning outcome. It was found that before the program, participant teachers' major objectives when teaching science could be grouped into six major aspects. They had objectives in developing students' ability to do scientific processes and scientific process skills and students' to develop some scientific attitudes. The intention to teach concepts of the Nature of Science explicitly was not found. These objectives were still constantly carried on while teachers participated in the program. It found that the program could make teachers recognize the relationship between the aims of science teaching and the teacher's views on science. Thus, they seemed to realize more the importance of the Nature of Science to their science teaching. After the program, it was found that all participant teachers extended or changed their objectives for science teaching to be more related to scientific process and process skills. There were new aspects of objectives of science teaching related to the Nature of Science recommended by one of the participant teachers. These objectives were to develop students' morals, ethics, and attitudes in using science and technology creatively and to develop students' abilities in imagination, communication, and decision-making.

After the program, it was found that all participant teachers continued to appreciate the uses of practical activities. These activities included observation, investigation, experimentation, exploration, and classification as the teaching approaches for the Nature of Science. Additionally, all participant teachers, except Ms. Juntra, appreciated the use of explicit instructional approaches of the Nature of Science in their science teaching. They appreciated that reflective questioning and indicating scientists' biographies might help improve students' conception of the Nature of Science, scientific attitudes, and attitude toward science.

One participant teacher, Ms. Juntra, thought that the discussion about the concepts of scientific process, scientific process skills, and characteristics of scientists after doing science activities was not suitable for Grade 1 students. She thought that students were too young to understand and participate in this type of discussion. So, she did not intend to use this discussion with her students in science class. This

finding was similar to Lederman's finding (1999) that one experienced teacher did not teach science in a manner consistent with her view of science. This is because she emphasized giving her students basic foundational knowledge of science and she felt the concepts of the Nature of Science were too abstract for her students to learn effectively.

After the program, there were two participant teachers, Ms. Dara and Ms. Juntra, who had an appreciation of applying scientific process and critical discussion in teaching Mathematics and Thai language. It appeared that teachers seemed to have the assumption that identifies the Nature of Science with a method of enquiry. They viewed science as a method of enquiry and "a powerful, and quite general, method of enquiry which can be learnt and then used in a wide range of other contexts, both scientific and non-scientific" (Driver *et al.*, 1996: 17).

3. Effects of the Program on Teachers' Teaching of the Nature of Science

It was found that after the program, all participant teachers in this research had students do practical activities relating to science inquiry. They taught science by using inquiry activities in accordance with some frequently used forms of inquiry activities noted by Eick (2000) and Lederman (1999). These frequently used forms of inquiry activities were inquiry demonstrations, data gathering and exploratory laboratories, student-generated discussion and questioning on a topic of study, student-centered research projects, and hands-on activities that developed student understanding of concepts of study.

Participant teachers in this research seemed to have, according to Akerson and Abd-El-Khalick's coding scheme (2003), Level 2 NOS instruction which referred to implicitly addressing some aspects of the Nature of Science in the teaching. The Level 2 NOS instruction included some instructional activities with "isolated statements" (p. 1032) which were consistent with some aspect of the Nature of Science, such as inquiry activities, but students did not have opportunities to consider or reflect explicitly on those aspects of the Nature of Science. It was found that some

participant teachers in this research mentioned some isolated statements such as exploration, and observation with their students during their science teaching. However, there was no discussion of or explanation about these terms. This finding was similar to what Tobin and McRobbie (1997) and Lederman (1999) found, that some teachers had adequate conceptions of the Nature of Science but they did not explicitly teach them. They emphasized using inquiry-oriented activities, demonstrations and laboratories, and students participating in collecting data, inferring explanations, and testing and revising the inferences. They emphasized only giving their students basic foundational knowledge of scientific concepts without a concern of concepts of the Nature of Science embedded in their teaching.

Although some participant teachers in this research appreciated the use of reflective questions with students such as what students did similar to scientists and the teaching of scientists' biography and work, it was not found they taught about these practically. It was found that they might have negative influences from some factors. Many other researcher had found various influential factors affecting teachers' teaching of the Nature of Science (Abd-El-Khalick and Lederman, 2000; Akerson and Abd-El-Khalick, 2003; Bencze *et al.*, 2003; Hipkins, *et al.*, 2004). For this research, the possible factors were teachers' level of experience in science teaching, perceptions of students and judgment about students' developmental readiness, science content-specific knowledge, science self-efficacy; and the realities of classroom constraints and teachers' teaching load. All of these factors seemed to limit teachers in preparation of science lessons and their willingness and confidence to use the explicit instructional approach for the Nature of Science with their students.

It was found that some participant teachers in this research applied the teaching of the same aspects of the Nature of Science as modelled within the training program into their classroom context. It was found that Ms. Dara brought an article about scientists' experiments on object free falling to her students and asked them to read it. She appreciated that the article about scientists' experiments on object free falling could motivate students' interests in doing scientific experiment. Ms. Jintana applied reflective questions such as what students did similar to scientists in her

science class after she attended the program. This finding was similar to the findings of Akerson and Abd-El-Khalick (2003). They found that their professional development program by modeling and supporting participant teacher in teaching the Nature of Science in the classroom could effectively enhance participant teacher's teaching of the same aspects of the Nature of Science as modeling lessons in classroom context. Thus, it could be inferred that teachers' appreciation of the importance of the Nature of Science and NOS PCK could be enhanced by teachers' personally applying training materials and the modeled teaching approaches of the Nature of Science to their science class.

In this research, it was found that the feedback of students from the use of the modelled activities could enhance teachers' classroom practice in teaching the Nature of Science. Ms. Jintana found that her students could describe scientific process and they seemed to develop good attitudes toward science after she asked the reflective questions about the Nature of Science. Ms Dara and Ms. Jintana had a willingness to develop more understanding of concepts of the Nature of Science and teach the Nature of Science in their science classes. These findings resembled with Bell and Gilbert (1994)'s suggestions that the supporting from students and taking account of students' thinking are the characteristic of effective teacher professional development. This would help teachers sustain their development.

Conclusions

According to the findings and discussion, this research could conclude that the professional development programme targeting the Nature of Science revealed that the use of explicit approaches for instruction of the Nature of Science and employing a teacher development program based on social constructivist perspectives exerted considerable influence on teachers' understanding of instruction of the Nature of Science. Participant teachers developed more contemporary views of the Nature of Science and appreciated more greatly the need to understand the Nature of Science as an objective of science teaching. They used more practical activities related to science processes in their science teaching and appreciated the importance, and the use, of

explicit instructional approaches relevant to the Nature of Science. However, there were some influential factors which constrained teachers' teaching of the Nature of Science practically and explicitly: their level of experience in science teaching, perceptions of students and judgment about students' developmental readiness, science content-specific knowledge, science self-efficacy, the realities of classroom constraints and teaching load.

Suggestions and Recommendations

1. Suggestions for implementation of the Program on the Instruction of the Nature of Science

In order to improve and apply an in-service primary school teacher professional development program on instruction of the Nature of Science, there were several points of concern listed under four major topics: facilitator's underpinning perspectives, specific concepts and instructional approaches of the Nature of Science, program activities, and program time schedules.

1.1 Facilitator's Underpinning Perspectives

It was found that to foster the effectiveness of the program, there were at least two points of concern.

1.1.1 The facilitator should recognize that there are generally two opposite views of any serious intellectual or epistemological questions or issues about the Nature of Science (Matthews, 1997). The Nature of Science itself is complicated and tentative as seen from its philosophical underpinning. No one could claim to have "knowledge of science as it really is" (Akerson *et al.*, 2000; Cleminson, 1990: 437). The purpose of teaching and learning about the Nature of Science should not be for teachers/facilitators to transmit their views of any aspects of the Nature of Science to make their students/learners agree with them and think as they think, but to have their

students/learners think, understand, and become interested in aspects of the Nature of Science (Matthews, 1997).

1.1.2 The facilitator should adopt the perspective of both personal and social constructivist views of learning and use it as a referent for making decisions about learning opportunities for teachers participating in this program. The facilitator should provide a supportive and trusting atmosphere during the discussion as well as equal opportunities for everybody to share the talk time in the discussion. The facilitator should also use collaborative teaching to foster teachers' development, by questioning, problem-posing and working together in small collaborative groups.

1.2 Specific concepts and instructional approaches of the Nature of Science

It was found that there were at least three points of concern with the specific concepts and instructional approaches which should be taught as learning outcomes of the training program.

1.2.1 The facilitator should specify and list the concepts and instructional approaches of the Nature of Science which would be the learning outcomes clearly. This is so the facilitator could purposefully keep the discussion about concepts and instructional approaches on track and could assess the development of the learners' understandings.

1.2.2 From the findings of this study, the concepts of NOS which should be emphasized as further specific concepts in the training program were roles and functions of scientific terms such as theory, law, and fact; subjective and perceptually bonded characteristics of scientific knowledge; scientific world view and basic assumption of NOS; limitation of science and scientific inquiry; and the social and cultural context in which scientists work.

1.2.3 The facilitator should emphasize helping learners to see the relationship between their views of science and their science instruction and the relationship between the Nature of Science and the objectives of science teaching and learning in accordance with the science curriculum. The learners should have a chance to clarify their existing views of science and their teaching. They should compare them with the specific concepts and instructional approaches of the Nature of Science. This is so the learners could reconstruct and make decisions to adjust their existing ideas and practice.

1.3 Program activities

There were at least five points of concern with the training activities to develop teachers' understandings of concepts and instructional approaches of the Nature of Science.

1.3.1 The facilitator should emphasize the discussion of the Nature of Science concepts after the learners read or are engaged in inquiry activities. The facilitator should encourage the learners to share their ideas and reconstruct their understanding after the discussion. If some inappropriate conceptions of the Nature of Science were found, the facilitator should have more additional activities to develop learners' understandings of those inappropriate concepts.

1.3.2 It was found that teachers seemed to need the samples of instructional approaches for specific science subject contents and specific scientific process skills. Thus, further design of activities to develop learners' understanding of the instructional approaches for the Nature of Science should emphasize modelling more specific science subject content integral to specific science process skills and the concepts of the Nature of Science.

1.3.3 According to teachers' needs and suggestions, there should be modelling of the Nature of Science instruction within teachers' classrooms or micro-teaching with real students from teachers' classes. Learners would have chances to

observe the facilitator teaching the new instructional approaches and discuss these to clarify the process and emphasis of the approaches. Akerson and Abd-El-Khalick (2003) suggested that this contextual professional support could enhance teachers' teaching of the same aspects of the Nature of Science as in modelled lessons to other classroom contexts.

1.3.4 The training activities for using scientific equipment, doing advance experiments, developing science teaching and learning materials and media, and outdoor activities would be interesting for teachers who attend the program.

1.3.5 For some technical terms in science and science education which teachers may not clearly understand, the facilitator should make lists of these technical terms to be included in learners' workbooks or as hand outs to learners in each period. These technical terms should also be discussed and clarified during the training program e.g. scientific inquiry and inquiry-oriented instructional approach.

1.4 Program Time Schedules

It was found that after school as the time set for the training course seemed to be unsuitable for lower primary school teachers in public primary school. According to teachers' suggestions, the program should be held in holidays, or before or during semester break. The program should use long continuous periods of time such as a half day, a whole day, or 2-5 days.

2. Recommendations for Further Research

2.1 The research findings of this study were from case study. Thus, the findings were specific and not generalized. In order to apply the findings, there should be a consideration of school context and setting included as part of the teachers' characteristics and school principal or administrators' support for teacher professional development.

2.2 This research focused on developing teachers' understanding of concepts and instructions of the Nature of Science. For further research, there should be the study on the relationship or the effects of teachers' implementation of their understandings and students' development of understandings of the Nature of Science and students' achievements in studying science.

Concluding Remark

Based on the case studies of four Thai lower primary school teachers' understanding and teaching of the Nature of Science, the research could achieve in-depth information of teachers' understanding of concepts and instructional approaches of the Nature of Science, their teaching and factors affecting their teaching of the Nature of Science. After developing and implementing an in-service primary school teacher professional development program on instruction of the Nature of Science with these participant teachers, the research could investigate the effectiveness of the program on developing teachers' understanding and teaching of the Nature of Science.

Before attending the program, it was found that most of the lower primary school teachers in this case had views of the Nature of Science on the whole in between traditional and contemporary views. They did not seem to recognize nor appreciate the understanding of the Nature of Science as cognitive learning outcomes to be explicitly taught and assessed in science classes. They used the implicit approach for teaching the Nature of Science with emphasis on studying scientific concepts and less emphasis on scientific activities. After attending the program, they had more contemporary views of science on the whole. They seemed to develop more appreciation to mention the understanding of the Nature of Science in their objectives of science teaching. It was found they used more practical activities relating to science process in their science teaching. Most of them appreciated the importance and the use of explicit instructional approaches of the Nature of Science in their science teaching by using reflective questioning and indicating scientists' biographies. There were still found some inappropriate conceptions of the Nature of Science and teachers

indicated they developed more understanding on some aspects of the Nature of Science. Most teachers still did not practically teach concepts of the Nature of Science that they appreciated. Some of them also did not appreciate the use of reflective discussion on the Nature of Science with students in the class. This may be because they had limited views on students' readiness to study concepts of the Nature of Science.

Thus, this training program seemed to achieve effectiveness in the level of initiating teachers' interests in concepts and instructional approaches of the Nature of Science. The researcher recognized that the development of teachers' understanding and teaching of the Nature of Science was an ongoing process. In order to develop teachers to have more adequate understanding of concepts and intention to teach the Nature of Science in their science class, the program should be improved in three major aspects: specific concepts and instructional approaches used with teachers, program activities, and time schedules. For the application of this training program to other contexts of the study, the researcher suggests that the facilitators should recognize the tentativeness of the Nature of Science. The facilitators should adopt the perspective of both personal and social constructivist views of learning and use this as a referent for making decisions about learning opportunities for teachers participating in this program. The facilitators should also specify and list the concepts and instructional approaches of the Nature of Science clearly. The learners should have chances to clarify their existing views of science and their teaching and should compare them with the concepts and instructional approaches of the Nature of Science. For applying the research findings to other study, the researcher recommends that there should be the consideration of research contexts and settings. This is because this study was interpretive and contextual bonded in its nature.

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APPENDICES

Appendix A

The Nature of Science Instruction Questionnaire

Nature of Science Instruction Questionnaire

Part I General Information

Please answer following questions according to your opinions and experiences.

1. Are you a specialist science teacher? Yes No
 2. What is your major in? _____
 3. How long have you taught science? _____
 4. Do you like science?
 Like Neutral Don't like
- Please give your reasons briefly:

5. Do you like teaching science?
 Like Neutral Don't like
- Please give your reasons briefly:

Part II Teaching of Science

Please answer following questions according to your opinions and experiences.

1. What are your objectives when teaching science?

2. What is the most important knowledge you think students should learn in science?

3. What are the important skills you think students should learn in science?

4. What are attitudes or habits of mind that students should gain from learning science?

5. What are the teaching approaches that you use in teaching science?

6. From the answers in Question 4, why do you use these approaches?

7. How do you know that students have learned science content, process skills and attitudes from your teaching?

8. Do you teach science by integrating with other subjects? Why or why not?

If you teach by integrating, how do you teach?

Part III Ideas about Nature of Science

The following statements are the ideas about science which students may hold. Consider and decide whether you understand them or not;

- (1) **If you do not understand, please tick (✓) in the first box,**
 (2) **If you understand, please tick (✓) in the box that best indicates your views of agree/disagree or neutral.**

Statements		responses					
		Do not understand	Strongly agree	agree	Neutral	disagree	Strongly disagree
1	Science is only a body of knowledge which explains concrete things, natural phenomena, and the world around us.						
2	Science is a process of exploring the unknown and discovering new things about our world and universe and how they work.						
3	Science is inventing and designing things and finding out ways to make people's lives better.						
4	Scientific knowledge is discovered by scientists who make observations of the world and carefully record and organize the facts or truths in a systematic way.						
5	Scientific knowledge is generated by scientists who attempt to explain and predict the natural phenomena based on the light of empirical evidences and logical reasoning.						
6	We can trust in scientific knowledge because it is confirmed by scientific method, scientific experiments and approved by scientific community.						
7	The words facts, concepts, principles, laws and theories in science have the same meaning as using in our daily lives.						
8	Scientific facts come from observation and experiments, and then, become scientific theories that in turn become laws.						
9	We can not have questions about scientific theories and laws. They are 100% true according to the reality and unchangeable. We have to remember and use them.						
10	When scientists make arguments, their personal bias does not have influence.						
11	Scientific knowledge can change if there is more evidence.						
12	We make senses of the world by careful and systematic study for making reasonably explanation of phenomena.						
13	The world and universe occur in consistent patterns, we can discover these patterns by using the intellect and aid of instruments.						

Statements		Do not understand	Strongly agree	agree	Neutral	disagree	Strongly disagree
14	Science is the most powerful way of understanding and discovering the truth of the natural world.						
15	Some matters cannot be examined usefully in a scientific way.						
16	Science can not completely explain the world and how it works. But, it can give accurate approximations.						
17	Scientists have no ideas about results before doing observations or experiments.						
18	Scientists do experiments to confirm scientific knowledge as proving the true or false of this knowledge.						
19	Every scientist always does scientific investigations in the same ways as a fixed set of steps to gain their scientific knowledge.						
20	Scientists try to explain and predict phenomena as the most accurate to the reality, although they know that they can not discover the absolute truth.						
21	We can not use imagination and creativity to get scientific knowledge.						
22	Scientists need to communicate their scientific results and require peer review.						
23	Scientists always work individually in laboratory and social affairs outside do not affect their work.						
24	Scientists are people like every body and participate in community both as specialists and as citizens.						
25	Science and technology affects society on the one hand, society affects science and technology on the other hand.						
26	Technology gets ideas from science and science gets new processes and instruments from technology.						
27	Scientists can do scientific research by do not have to consider much about ethical principles.						
28	Science is only scientists' work. Other group of people in society can not participate.						
29	Today scientists develop scientific knowledge from previous knowledge according to history.						

Appendix B

The Semi-structured Interview Question Items

Interview question items for lower primary school teachers who teach science

Objectives: In this interview there are three objectives:

1. To discover information about basic education and teacher training, teaching experience, job loading, working contexts and interests of participant teacher. This information will be used as fundamental data for developing a primary school teacher professional development program on the nature of science instruction;
2. To discover participant teacher's understanding of the nature of science instruction in the aspects of curriculum, the nature of science concepts, teaching approaches for the nature of science concepts and general teaching approaches for science subject;
3. To discover participant teacher's opinions on factors which influence the nature of science instruction.

Description: There are three main parts in this interview, with series of questions in each part.

Part 1: Fundamental information of participant teacher

- 1.1) What is the faculty (division) which you graduated from?
- 1.2) How long have you taught science?
- 1.3) Do you have to teach subjects other than science? What are they?
- 1.4) Do you have non-teaching responsibilities in your school?
- 1.5) Have you ever attended teacher training programmes? Can you tell me about it? Do you apply knowledge from those training programmes in your work? How?
- 1.6) Do you like to teach science? In your opinion, are you skilful in teaching science? How do you feel when teaching science?
- 1.7) Are you satisfied with your teaching of science? Can you describe your reasons for this satisfaction?
- 1.8) If there were to be a training programme for science teaching, how would it be useful and most appropriate for you?
- 1.9) Have you ever received any supervisions in your school and how?
- 1.10) How do the administrators in your school support or give vision for your science teaching?

Part 2: Understanding of the nature of science instruction

- 2.1) What are your general approaches for teaching science? Please give some examples in the aspects following:
 - Planning the lessons and preparing instructional media;
 - Choosing and desiring learning activities for each science unit or lesson;
 - Teaching and learning approaches and techniques such as lecturing, demonstrating, experimentation, observation, inquiry, etc.;
 - creating assessment and evaluation tasks.
- 2.2) In the basic educational curriculum for science group of subjects, the eighth content strand is "the nature of science and technology". How do you think about teaching this strand in any aspects such as the

- importance of and teaching approaches to this strand;
- 2.2) In your opinion, what are the characteristics of science or the nature of science in following aspects:
- Definition of science (what is science?)
 - How does science relate with technology and society?
 - How do scientists gain their scientific knowledge?
 - What are the characteristics of scientific knowledge? (What knowledge is scientific knowledge and what knowledge is not? How do we identify the difference?)
 - What are facts, concepts, laws, principles and theories which are kinds of scientific knowledge? How are they different?
 - What are the characteristics of scientist?
- 2.4) In your opinion, how do we teach science for relating and reflecting the nature of science? (Please give example of any teaching activities and explain how these activities relate to or reflect the nature of science.)

Part 3: Opinion on factors which influence the nature of science instruction

- 3.1) Do you think that your science teaching relates to or reflects the nature of science? Why? How?
- 3.2) What factors in your experience do you think influence your teaching about the nature of science? Can you identify how they influence your teaching? For example:
- Your basic education and teaching experience;
 - Classroom management;
 - Time management for planning and preparing the lessons;
 - Students' learning behaviours and students' context such as their family, economic and society;
 - Cooperation and support from students' parents and school administrators such as documents, media, learning resources and supervision.

Appendix C

Table of Coding Lists for Concepts of the Nature of Science

Appendix Table 1 Coding Lists for Concepts of the Nature of Science

Aspects of the Nature of Science	Code
Definitions of science	1.00
Defining science	1.01
Interdependence of science and other disciplines	1.02
Scientific knowledge	2.00
Source of scientific knowledge	2.01
Nature of scientific knowledge	2.02
The validity of scientific knowledge	2.02.1
Kinds of scientific knowledge	2.02.2
Specific characteristics of scientific knowledge	2.02.3
Development of scientific knowledge	3.00
Scientific world view and basic assumptions of the nature	3.01
The world is understandable	3.01.1
The universe occur in consistent patterns	3.01.2
Discover patterns in all of nature by use intellectual and aid of instruments	3.01.3
Science cannot provide complete answers to all questions	3.01.4
Science has inherent limitations	3.01.5
Scientific method and process	3.02
Not only one way to do science	3.02.1
No universal step-by-step scientific method	3.02.2
Characteristics of scientific inquiry	3.03
Science is an attempt to explain and predict phenomena	3.03.1
Logical-reasoning, imagination, and curiosity attribute scientific inquiry	3.03.2
Communicating of scientific results attributes scientific inquiry	3.03.3
Scientific process skills	3.04
Scientists use science process skills to accomplish their works	3.04.1
Characteristics of scientists and scientific attitudes	4.00
Curiosity	4.01
Persevering	4.02
Reasoning	4.03
Trustworthy	4.04
Circumspect	4.05
Broad-minded	4.06
Interrelation between science, technology, and society	5.00
Interrelation between science and technology	5.01
Interrelation between science and society	5.02
Science is part of intellectual, social and cultural traditions	5.02.1
The history of science reveals both an evolutionary and revolutionary character	5.02.2
People from all cultures contribute to science	5.02.3
Science is a complex social activity	5.02.4
There are general accepted ethical principles in the conduct of science	5.02.5

Appendix D

Coding Scheme for the NOS Instruction

Appendix Table 2 Coding Scheme for the Nature of Science Instruction

Aspects of Instruction of NOS	Code
Objectives of science teaching	T 1.00
Teaching approaches	T 2.00
Teaching techniques	T 2.01
Focused content	T 2.02
Media & resources	T 2.03
Assessment	T 2.04
Classroom setting	T 3.00
Introductory of lesson	T 4.00
Teaching and learning activity	T 5.00
Conclusion of lesson	T 6.00
Factors affecting teaching	T 7.00

Appendix E

Analysis Task for NOSI Questionnaire

Analysis Task for the Nature of Science Instruction (NOSI) Questionnaire

Part I: General Information

Questions are about:

- 1) Majoring of subject of teaching
- 2) Majoring of graduated file of study
- 3) Teaching experiences
- 4) Attitude toward science
- 5) Attitude toward teaching science

Objectives of questioning: For gathering the general information of participant teachers and using data as a part of analysis about the factors influence understanding of the Nature of Science instruction

Part II: Teaching of Science

There are two aspects of teacher's understanding which are assessed in this part.

- 1) Understanding of the Nature of Science concepts
- 2) Understanding of the Nature of Science instructional approaches

Understanding of the Nature of Science concepts

Question 1: *What are your objectives when teaching science?*

This question assesses teacher's understanding on the aspects of;

- 1) Definition of science,
- 2) Development of scientific knowledge in the sub-topics of characteristics of scientific inquiry and Scientific process skills,
- 3) Characteristics of scientists and scientific attitudes,
- 4) Interrelation between science, technology, and society.

Assessment task: If teacher have completely understandings of these aspects, teacher should be able to state about these aspects at least roughly in the objectives of teaching science.

Question 2& 3: *What is the most important knowledge you think students should learn in science?*

What are the important skills you think students should learn in science?

These questions assess teacher's understanding on the aspects of;

- 1) Definition of science,
- 2) Scientific knowledge,
- 3) Development of scientific knowledge,
- 4) Characteristics of scientists and scientific attitudes,
- 5) Interrelation between science, technology, and society.

Assessment task: If teacher have completely understandings of these aspects, teacher should be able to state about these aspects at least roughly in the contents and skills which students should learn.

Question 4: *What are attitudes or habits of mind that students should gain from learning science?*

This question assesses teacher's understanding directly on the aspects of: scientific attitudes.

Assessment task: If teacher have completely understandings of these aspect of scientific attitudes, teacher should be able to state characteristics of scientific attitudes.

Question 5 & 6: *What are the teaching approaches that you use in teaching science? Why do you use these approaches?*

This question assesses teacher's understanding on the aspects of;

- 1) Definition of science,
- 2) Development of scientific knowledge in the sub-topics of scientific method and process, and characteristics of scientific inquiry.

Assessment task: Teacher's answers about the teaching process will reflect teacher's understandings of the Nature of Science in these aspects. For example, if teacher thinks that teaching science is to transfer content for students to remember and use in their life, it can be inferred that this teacher views science as only body of knowledge (the traditional view of the Nature of Science concepts). In contrast, if teacher thinks that teaching science is to teach students about process and skills of scientific inquiry for students can inquire their own knowledge and solve their problems by themselves, it can be inferred that this teacher views science as process of scientific inquiry (the contemporary view of the Nature of Science concepts).

Question 7: *How do you know that students have learned science about contents, process skills and attitudes from your teaching?*

This question assesses teacher's understanding on the aspects of;

- 1) Definition of science,
- 2) Scientific knowledge,
- 3) Development of scientific knowledge,
- 4) Characteristics of scientists and scientific attitudes,
- 5) Interrelation between science, technology, and society.

Assessment task: If teacher have completely understandings of these aspects, teacher should be able to state about these aspects at least roughly in the contents and processes which students have learned.

Question 8: *Do you teach science by integrating with other subjects? Why or why not? If you teach by integrating, how do you teach?*

This question assesses teacher's understanding on the aspects of: Definition of science directly to the sub-aspect of Interdependence of science and other disciplines.

Assessment task: If teacher have understandings of these aspects, teacher should state about these aspects in the reasons of teaching as integrating subjects or content topics. For example, the calculation skills in Mathematics can support the development of scientific knowledge, thus this can be taught as integrated with science subject.

Understanding of the Nature of Science instructional approaches

Each question assesses teacher's understandings on;

Question 1: Objectives of science teaching

Question 2, 3, 4: Intended outcomes of learning science in the contents, skills and attitudes domains

Question 5 &6: Teaching approaches as relating to the nature of subject

Question 7: Assessment of the science instruction

Question 8: Teaching approaches for science as integrated subject

Assessment task: If teacher have understandings of these aspects, teacher's answers should be relate with the effective teaching approaches stated in the Thai science standards documents and the international standards.

Part III Ideas about Nature of Science

Each statement is supposed to assess teacher's understanding of the Nature of Science concepts directly. There are two main task of analysis.

- 1) If teacher does not have understanding on any assessed concepts, this can be evaluated from the sign (✓) in the first box, "Do not understand".
- 2) If teacher do have understand on any assessed concepts, this can be estimated their understanding from the sign (✓) in the other five boxes.

Every statement, except items 3, 7, and 8 are supposed to estimated teacher's views on the Nature of Science concepts as traditional view or contemporary view. The third and seventh items will be estimated level of teacher's understandings as misconception, naïve view, or correct conception.

For the evaluation of the rating scale, there are two ways of giving marks for each statement according to its view, positive to traditional view or positive to contemporary view of the Nature of Science concepts.

The positive statements to traditional view are in the items; 1, 4, 9, 10, 13, 14, 17, 18, 19, 21, 23, 27 and 28

These items can be classified into several groups according to the NOS conceptual scheme as following;

- 1) Definition of science-- items; 1
- 2) Scientific knowledge-- items; 4, 9, and, 10
- 3) Development of scientific knowledge-- items; 13, 14, 17, 18, 19 and 21
- 4) Interrelation between science, technology, and society-- items; 23, 27 and 28

The positive statements to contemporary view are in the items; 2, 5, 6, 11, 12, 15, 16, 20, 22, 24, 25, 26, and 29

These items can be classified into several groups according to the NOS conceptual scheme as following;

- 1) Definition of science-- items; 2
- 2) Scientific knowledge-- items; 5, 6, and 11
- 3) Development of scientific knowledge-- items; 12, 15, 16, 20, and 22
- 4) Interrelation between science, technology, and society-- items; 24, 25, 26, and 29

Criteria for scores

1. The item which answered in the first box, "Do not understand", will score as 0 point. This item will be cut out of the calculation of the whole questionnaire mean. This item will be analysed as the responder does not have understanding of the concept in this item.
2. The third, seventh, and eighth items will be cut out of the calculation of the whole questionnaire mean. These items will be scored and analysed as separate item.

Each statement will be given scores as;

Do not understand	score	0	point
Strongly agree	score	1	point
Agree	score	2	points
Neutral	score	3	points
Disagree	score	4	points
Strongly disagree	score	5	points

Analysis of each item

If each item have score;

- 0 point means that: the responder does not have understanding of the concept in this item.
- 1-2 points mean that: the responder has Alternative conception of the concept in this item.
- 3 points mean that: the responder has naïve view of the concept in this item.
- 4-5 points mean that: the responder has correct conception of the concept in this item.

3. The items which are positive statements to traditional view or positive statements to contemporary view will be scored and analysed as following;

The positive statements to traditional view will be given score as;

Strongly agree	score	1	point
Agree	score	2	points
Neutral	score	3	points
Disagree	score	4	points
Strongly disagree	score	5	points

The negative statements to contemporary view will be given score as;

Strongly agree	score	5	points
Agree	score	4	points

Neutral	score	3	points
Disagree	score	2	points
Strongly disagree	score	1	point

Analysis of the whole question items

For finding of mean of the whole question items, score from each items will be sum together and dived by the total number of the items (this number already cut the 3, 7, and 8 items and “do not understand” items off).

The analysis will assume that if a whole questionnaire has mean score in the range of;

1.000 – 1.509 points mean that: on the whole, the responder has strongly traditional view on the Nature of Science concepts.

1.510 – 2.509 points mean that: on the whole, the responder has traditional view on the Nature of Science concepts.

2.510 – 3.509 points mean that: on the whole, the responder has both traditional view and contemporary view on the Nature of Science concepts.

3.510 – 4.509 points mean that: on the whole, the responder has contemporary view on the Nature of Science concepts.

4.510 – 5.000 points mean that: on the whole, the responder has strongly contemporary view on the Nature of Science concepts.

The Table 2 shows the summary of answers’ trends according to the different views.

Appendix Table 3 Summary of Answers’ Trends According to the Different Views

Statements		Strongly agree	agree	Neutral	disagree	Strongly disagree
1	Science is only a body of knowledge which explains concrete things, natural phenomena, and the world around us. (1.01)	Traditional		Contemporary		
		←-----→				
2	Science is a process of exploring the unknown and discovering new things about our world and universe and how they work. (1.01)	Contemporary			Traditional	
		←-----→				
3	Science is inventing and designing things and finding out ways to make people’s lives better. (1.01)	Misconception Naïve		Right		
		←-----→				
4	Scientific knowledge is discovered by scientists who make observations of the world and carefully record and organize the facts or truths in a systematic way.(2.01)	Traditional		Contemporary		
		←-----→				
5	Scientific knowledge is generated by scientists who attempt to explain and predict the natural phenomena based on the light of empirical evidences and logical reasoning. (2.01)	Contemporary		Traditional		
		←-----→				

Appendix Table 3 (Continued)

	Statements	Strongly agree	agree	Neutral	disagree	Strongly disagree
6	We can trust in scientific knowledge because it is confirmed by scientific method, scientific experiments and approved by scientific community. (2.02.1)	Contemporary		Traditional		
		←-----→				
7	The words facts, concepts, principles, laws and theories in science have the same meaning as using in our daily lives. (2.02.2)	Misconception	Naïve	Right		
		←-----→				
8	Scientific facts come from observation and experiments, and then, always become scientific theories that in turn become laws. (2.02.2)	Misconception	Naïve	Right		
		←-----→				
9	We can not have questions about scientific theories and laws. They are 100% true according to the reality and unchangeable. We have to remember and use them. (2.02.3)	Traditional		Contemporary		
		←-----→				
10	When scientists make arguments, their personal bias does not have influence. (2.02.3)	Traditional		Contemporary		
		←-----→				
11	Scientific knowledge can change if there is more evidence. (2.02.3)	Contemporary		Traditional		
		←-----→				
12	We make senses of the world by careful and systematic study for making reasonably explanation of phenomena. (3.01.1-.2)	Contemporary		Traditional		
		←-----→				
13	The world and universe occur in consistent patterns, we can discover these patterns by using the intellect and aid of instruments. (3.01.3)	Traditional		Contemporary		
		←-----→				
14	Science is the most powerful way of understanding and discovering the truth of the natural world. (3.01.4-.5)	Traditional		Contemporary		
		←-----→				
15	Some matters cannot be examined usefully in a scientific way. (3.01.4-.5)	Contemporary		Traditional		
		←-----→				
16	Science can not completely explain the world and how it works. But, it can give accurate approximations. (3.01.5)	Contemporary		Traditional		
		←-----→				
17	Scientists have no ideas about results before doing observations or experiments. (3.02)	Traditional		Contemporary		
		←-----→				
18	Scientists do experiments to confirm scientific knowledge as proving the true or false of this knowledge. (3.02)	Traditional		Contemporary		
		←-----→				
19	Every scientist always does scientific investigations in the same ways as a fixed set of steps to gain their scientific knowledge. (3.03.1-.2)	Traditional		Contemporary		
		←-----→				
20	Scientists try to explain and predict phenomena as the most accurate to the reality, although they know that they can not discover the absolute truth. (3.03.3)	Contemporary		Traditional		
		←-----→				
21	We can not use imagination and creativity to get scientific knowledge. (3.03.4)	Traditional		Contemporary		
		←-----→				
22	Scientists need to communicate their scientific results and require peer review. (3.03.5)	Contemporary		Traditional		
		←-----→				
23	Scientists always work individually in laboratory and social affairs outside do not affect their work. (5.02.4)	Traditional		Contemporary		
		←-----→				
24	Scientists are people like every body and participate in community both as specialists and as citizens. (5.02.1)	Contemporary		Traditional		
		←-----→				

Appendix Table 3 (Continued)

Statements		Strongly agree	agree	Neutral	disagree	Strongly disagree
25	Science and technology affects society on the one hand, society affects science and technology on the other hand. (5.00)	Contemporary		Traditional		
		←-----→				
26	Technology gets ideas from science and science gets new processes and instruments from technology. (5.01)	Contemporary		Traditional		
		←-----→				
27	Scientists can do scientific research by do not have to consider much about ethical principles.(5.02.5)	Traditional			Contemporary	
		←-----→				
28	Science is only scientists' work. Other group of people in society can not participate. (5.02.3)	Traditional			Contemporary	
		←-----→				
29	Today scientists develop scientific knowledge from previous knowledge according to history. (5.02.2)	Contemporary		Traditional		
		←-----→				

Appendix F

Sample of a Field Note

Field Note of Case 1

Observer: T.P.
Date: 11/06/2004

Participant: MS. Dara
Time: 12.55-01.55 pm.

Place: Classroom G1/1

CODE	OBSERVE	COMMENT
<p>T 3.00</p>	<p>Classroom setting</p>	
<p>T 1.00</p>	<p>Objectives: Classification of living and non-living things</p>	
<p>T 2.02</p>	<p>Learning unit: Environment</p>	
<p>T 2.03</p>	<p>Learning media and resources:</p> <p style="padding-left: 20px;">2.5 2 picture posters of natural forest</p> <p style="padding-left: 20px;">2.6 2 worksheets of living and non-living things</p>	
<p>T 4.00</p>	<p>Teaching & learning activities</p> <p><i>Introduction of lesson</i></p>	
<p>T2.01</p>	<p>-Teacher told students that she would bring them outside and let students close their eyes.</p> <p>-Teacher put 2 picture posters of natural forest on the black board.</p> <p>-Students opened eyes and teachers asked whether student used to go to water fall and asked one students to point out where the water fall was in the picture.</p> <p>-Teacher asked students to tell the difference between two pictures.</p> <p>-Teacher asked students to tell what are living things and non-living things from the pictures</p>	

CODE	OBSERVE	COMMENT
<p>T 5.00 T2.01</p>	<p><i>Teaching and learning activity</i></p> <ul style="list-style-type: none"> -Teacher gave a worksheet to each group of students and informed students to work in group look at the picture in the worksheet and find out living and non-living things and chose one group presenter to report the findings in front of the class. -Teacher gave students time to complete their work -Student presenter reported their findings in front of the class. -Teacher asked students to conclude the findings again. -Teacher gave new worksheet to each student and informed students to look at the picture and draw the picture of living things in one empty box and non-living things in another box in the worksheet. 	
<p>T 6.00 T 2.04</p>	<p><i>Conclusion of lesson</i></p> <ul style="list-style-type: none"> -Teacher discussed with students for concluding the important characteristics of living and non-living things and the difference between living and non-living things. -Teacher asked students to write the conclusion in the worksheet. 	

Appendix G

Sample Table of Data Cross Checking

Appendix Table 4 Data Cross Checking of Case 1 NOS Concepts

NOS Conceptual Scheme	Rating scales		Open ended findings	Interview
	NOS items	responses		
1. <u>Definitions of science</u>		Trad.-Cont. & Mis.		
01. Defining science (e.g. Science as both body of knowledge and process to explain about natural phenomena)	1. Science is only a body of knowledge which explains concrete things, natural phenomena, and the world around us. (1.01)	-Agree	-Inquiry process, acquire knowledge by observation, exploration, investigation, and doing research systematically	-Science must be taught by emphasize learning process -Students should learn by process to know observation, analysis, synthesis, and application of knowledge - In science has observation, analysis and synthesis thinking and application
	2. Science is a process of exploring the unknown and discovering new things about our world and universe and how they work. (1.01)	-Agree		
	3. Science is inventing and designing things and finding out ways to make people's lives better. (1.01)	-Agree		

Appendix H

Sample Table of Cross Case Analysis

Appendix Table 5 Cross Cases NOS Conceptions

NOS	Dara	Napar	Juntra	Jintana
Over all	3.696 contemporary view	3.250 traditional and contemporary view	3.423 traditional and contemporary view	3.423 traditional and contemporary view
1. Definition of Science	Mix view Emphasize contemp. > trading.	Mix view Emphasize contemp. > tradit.	Mix view Emphasize contemp. > tradit.	Mix view Emphasize trading. > contemp.
	science is about: - process of knowledge inquiry - observation, - exploration, - investigation, - systematic researching - analysis, - synthesis, - application	science is about: - scientific process and process skills, - analysis thinking and reasoning, - problem solving process, - application of knowledge to daily life	science is about: - scientific process and process skills, - reasoning	science is about: - natural things sensible and closed to us
	science = techno. alternative conception	science = techno. naïve view	science = techno. alternative conception	science = techno. alternative conception
2. Scientific Knowledge				
2.1 Source of scientific knowledge	<i>Mix view</i> Both discovery and generation	<i>contemp</i> > <i>trading</i> . generation> discovery	<i>contemp</i> > <i>trading</i> . generation> discovery	<i>Mix view</i> Both discovery and generation
	- self study - direct experiences			studying existing knowledge -demonstration -observation -discussion -critical thinking
	<i>contemp</i> . - recognize the social and cultural context, part of traditions	<i>traditional</i> - lack concern human and social context	<i>mix</i> . - recognize the social and cultural context, part of traditions	<i>contemp</i> . - recognize the social and cultural context, part of traditions

Appendix Table 6 Cross Cases NOS Instruction and Factors

NOS Instruction	Dara	Napar	Juntra	Jintana
1. Objectives of science teaching	Develop students' abilities in performing process of knowledge inquiry by observing, exploring, investigating, and researching systematically.	Develop students' abilities in critical thinking, in performing scientific process and skills, in solving problems systematically, and in application of knowledge to daily life.	Develop students' abilities in performing scientific process and skills	Develop students' understanding of environment surrounding and awareness of values and uses of natural environment for the most benefits
	Important topics - living things and living processes	Important topics - science, technology and environment	Important topics - conservation of environment	Important topics - environment
	Emphasis - Developing students' skills in observation, classification, acquiring of knowledge, and application of knowledge for self improvement in daily life - have good attitude toward learning science	Emphasis - Developing students' skills in rational thinking, researching, and problem solving - recognize about the relationship between science, technology and environment	Emphasis - Students were encouraged to express their thought and deeds - developing students' skills in rational thinking, observation, experimentation, and problem solving	Emphasis -Developing students' skills in observing, questioning, orderly working, cooperating in group working, expressing of ideas, and creative thinking -Students should be able to test things which they have observed for finding out facts. -Students should be practiced to be observant, curious, rational, disciplinary, creative, and moral

BIOGRAPHICAL DATA

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