

A DEVELOPMENT OF PROFESSIONAL DEVELOPMENT PROGRAM FOR
ENHANCING TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE
AND ITS IMPLEMENTATION IN THE CLASSROOM

A DISSERTATION
BY
SUTHAWAN MEESRI

Presented in Partial Fulfillment of the Requirements for the
Doctor of Education Degree in Science Education
at Srinakharinwirot University
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Suthawan Meesri

TABLE OF CONTENTS

Chapter		Page
1	INTRODUCTION	
	Background.....	1
	Objectives of the Study.....	4
	Significance of the Study.....	4
	Scope of the Study.....	5
	Definition of Terms.....	6
	Theoretical Framework.....	9
	Research Hypotheses.....	13
2	REVIEW OF THE LITERATURE	
	The Nature of Science.....	14
	Nature of Science in Science Education.....	19
	The Nature of Science Teaching Approach.....	26
	Questionnaires for Assessing Understanding of the Nature of Science.....	28
	The Role of the Teacher in the Nature of Science Instruction.....	30
	Improving Teachers' Pedagogical Approaches for the Nature of Science.....	34
	Designing Professional Development.....	41
	Evaluating Professional Development.....	49
3	METHODOLOGY	
	Stage 1: Studying the Context and Problem of the Nature of Science Teaching.....	57
	Stage 2: Designing the Professional Development Program	58

TABLE OF CONTENTS (continued)

Chapter	Page
3 METHODOLOGY (continued)	
Stage 3: Draft of Professional Development Program Evaluation.....	60
Stage 4: Conducting a Pilot Study.....	61
Stage 5: Program Implementation.....	61
Stage 6: Program Evaluation after Implementation.....	65
4 FINDINGS	
Results of the Teachers' Understanding of the Nature of Science.....	66
Results of the Teachers' Teaching of the Nature of Science.....	76
Results from Teachers' Self-Reflection on Their Improving of the Nature of Science Instruction.....	83
Results from the Study of Students Learning Outcomes.....	84
5 CONCLUSION AND DISCUSSION	
Conclusions.....	90
Discussions.....	91
Recommendations.....	93
BIBLIOGRAPHY.....	94
APPENDIX.....	101
Appendix A: Example of a Science Story Activity in Professional Development Program.....	102
Appendix B: Results of Professional Development Program Evaluation.....	112

TABLE OF CONTENTS (continued)

Chapter	Page
APPENDIX	
Appendix C: Results of Teachers' Responses to Five-pointed Likert Scale to the Nature of Science Questionnaire.....	118
Appendix D: Example of some Items in an Open-ended the Nature of Science Questionnaire.....	122
Appendix E: Examples of Data Cross Checking of Teacher's Conception of the Nature of Science.....	129
VITAE.....	131

LIST OF TABLES

Table		Page
1	Eighteen Strategies for Professional Learning.....	46
2	Critical Levels of Professional Development Evaluation.....	50
3	Teachers' Responses to the Nature of Science Statements Before and After Attending the Program.....	68
4	Teachers' Mean Score of All Question Items Before and After Attending the Program.....	71
5	Change in Views of the Nature of Science Aspects Results from Open-ended Questionnaire.....	74
6	The Frequency of Each Level in Each Teaching Session.....	82
7	Possible Sources for Improving Their Teaching of the Nature of Science.....	83
8	Students' Understanding of the Nature of Science.....	85

LIST OF FIGURES

Figure	Page
1 An Intersection of Social Studies Making of a Description of the Nature of Science.....	15
2 The Framework of the Professional Development Program.....	54
3 The Overview of the Research Methodology.....	56

การพัฒนาโปรแกรมฝึกอบรมครูเพื่อเสริมสร้างความเข้าใจ
เรื่องธรรมชาติของวิทยาศาสตร์ และการนำไปใช้ในชั้นเรียน

บทคัดย่อ
ของ
สุธาวัลย์ มีศรี

เสนอต่อบัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ เพื่อเป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาการศึกษาดุขฎีบัณฑิต สาขาวิทยาศาสตร์ศึกษา
ตุลาคม 2550

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ธรรมชาติของวิทยาศาสตร์ และการนำไปใช้ในชั้นเรียน. ปริญญาโท กศ.ด.
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เหมะประสิทธิ์, ผู้ช่วยศาสตราจารย์ ดร. ปรินทร์ ชัยวิสุทธิทางกูร.

งานวิจัยนี้เป็นการศึกษาผลของโปรแกรมพัฒนาวิชาชีพที่มีต่อความเข้าใจเรื่องธรรมชาติของ
วิทยาศาสตร์ และการจัดการเรียนรู้ของครูวิทยาศาสตร์ โดยโปรแกรมนี้แบ่งออกเป็นสองระยะ กล่าวคือ
1) การพัฒนาความเข้าใจของครูเรื่องธรรมชาติของวิทยาศาสตร์ 2) การพัฒนาความรู้ด้านการสอน
ธรรมชาติของวิทยาศาสตร์ ในระยะที่ 1 มีครูผู้เข้าร่วมโปรแกรมจำนวน 15 คน ระยะที่ 2 มีครูผู้เข้าร่วม
โปรแกรมจำนวน 6 คน ซึ่งเป็นผู้ที่ได้ร่วมเข้ารับการฝึกอบรมในระยะที่ 1 ครูทั้ง 6 คนนี้ได้ทำการ
ปฏิบัติการสอนจริงในชั้นเรียนสามครั้ง โดยสอนธรรมชาติของวิทยาศาสตร์หลังจากที่ผ่านการพัฒนา
ความเข้าใจเรื่องธรรมชาติของวิทยาศาสตร์จากระยะที่ 1

วิธีที่ใช้ในโปรแกรมพัฒนาวิชาชีพครูนี้ประกอบด้วย 1) การฝึกอบรมเชิงปฏิบัติการ 2) การ
สาธิตการสอน 3) การปฏิบัติการสอนจริง 4) บันทึกสะท้อนการเรียนรู้ของครู และ 5) การให้ความ
ช่วยเหลือ แนะนำ ผู้วิจัยทำการประเมินแนวคิดเรื่องธรรมชาติของวิทยาศาสตร์ของครูทั้งก่อนและ
ภายหลังเข้าร่วมโปรแกรมโดยใช้แบบสอบถาม 2 ชุด คือ 1) แบบสอบถามมาตรวัดประเมินค่า 5 ระดับ
(five-point Likert scale) และ 2) แบบสอบถามปลายเปิด ร่วมกับการสัมภาษณ์กึ่งโครงสร้าง ในส่วน
ของการประเมินภาคปฏิบัติ ครูแต่ละคนทำการสอน 3 ครั้ง ซึ่งผู้วิจัยเก็บข้อมูลจากการสังเกตในชั้น
เรียน แบบบันทึกภาคสนาม แผนการจัดการเรียนรู้ และวิเคราะห์ข้อมูลเหล่านี้เพื่อหาว่าครูมีการ
เปลี่ยนแปลงวิธีการสอนสำหรับเรื่องธรรมชาติของวิทยาศาสตร์อย่างไร และได้นำเสนอประเด็น
ธรรมชาติของวิทยาศาสตร์ในระหว่างทำการสอนทั้ง 3 ครั้งนั้นอย่างไร

ผลการวิเคราะห์ข้อมูลพบว่าก่อนเข้าร่วมโปรแกรม ครูมีพื้นฐานและความเข้าใจเรื่องธรรมชาติ
ของวิทยาศาสตร์มาบ้าง อย่างจำกัด ไม่สามารถอธิบายได้อย่างชัดเจน และไม่เพียงพอต่อการสอน
เรื่องธรรมชาติของวิทยาศาสตร์ ครูไม่ได้ให้ความสำคัญต่อการสอนเรื่องธรรมชาติของวิทยาศาสตร์ทั้ง
วัตถุประสงค์การจัดการเรียนรู้ ตลอดจนผลการเรียนรู้ที่คาดหวังของนักเรียน หลังจากเข้าร่วมโปรแกรม

ผลการศึกษาแสดงให้เห็นถึงการเปลี่ยนแปลงของครูด้านแนวคิดเรื่องธรรมชาติของวิทยาศาสตร์จาก
อย่างง่ายไปสู่การให้รายละเอียดได้มากขึ้น สามารถอธิบายได้โดยใช้ภาษาของตนเอง และยกตัวอย่าง
สนับสนุนความคิดได้ ครูยังสามารถทำการสอนประเด็นทางธรรมชาติของวิทยาศาสตร์ได้อย่างชัดเจน
แทนการสอนแบบเป็นนัยได้ และตระหนักถึงความสำคัญของการสอนเรื่องธรรมชาติของวิทยาศาสตร์
แก่นักเรียน ผลของการศึกษานี้มีความสำคัญต่อแนวทางการพัฒนาการฝึกหัดครูและการปฏิรูป
การศึกษาด้านวิทยาศาสตร์ให้เกิดผลสำเร็จ

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This research aimed to study the effects of a professional development program on science teachers' views of nature of science and instructional practice. The professional development program consisted of two phases: 1) developing teachers' understanding of the nature of science 2) developing teachers' pedagogical content knowledge for the nature of science instruction. In Phase 1, participants were fifteen secondary science teachers. In Phase 2, participants were six teachers who had participated in Phase 1. These teachers were asked to teach the nature of science in their real classroom settings after they had developed their understanding of the nature of science from Phase 1.

Learning strategies used in this program consisted of 1) workshops 2) model lessons 3) teaching practice and 4) reflective writing and 5) coaching and mentoring. The researcher tracked the changes in pre- and post- views of the nature of science in each teacher by using 2 questionnaires: 1) five-point Likert scale questionnaire and 2) the open-ended questionnaire in conjunction with individual interviews. To evaluate teachers' practice, three teaching sessions were assigned to the teachers. Classroom observation, field notes and lessons plans were collected and analyzed to find how teachers changed their pedagogical approaches for nature of science instruction and how they addressed aspects of nature of science through three teaching sessions.

The data indicated that prior to attending the program teachers had some ideas about aspects of the nature of science, but they could not clearly explain these concepts verbally. Their understanding of the nature of science was generally inadequate for science

teaching. They did not emphasize concepts of the nature of science as their goals of instruction and students' learning outcomes. After the teachers attended the program, they changed their views from naïve/misconception to informed views in most of the nature of science issues. They could articulate the meaning of the aspect of the nature of science in his/her own words and provide examples. Through three teaching sessions, the teachers also improved in their science pedagogy by explicitly addressing nature of science issues in science classes instead of implicit or didactic teaching on the nature of science. From teachers' self-reflection the possible sources for improving their teaching on the nature of science were activities about science stories, reflective writing and model lessons. The results demonstrated the important implications for teacher education as well as the successful implementation of current reforms.

CHAPTER ONE

INTRODUCTION

Background

For a long time, the nature of Science (NOS) has been one of the major goals of science instruction and the prerequisite of science literacy of many countries (Lederman. 1992; The National Science Education Standards (NRC). 1996; McComas; et al. 2000). Conceptions and instruction of the NOS have been indicated explicitly in many reformed curriculum documents in both United States (American Association for the Advancement of Science (AAAS). 1993) and foreign reform and standards documents (McComas; & Olson. 2000).

Scientific inquiry and NOS provide a meaningful foundation for the learning of science. The advantage of teaching what science is, how it works, the limitations, and how scientific knowledge comes to be accepted, is to help students think better and be better consumers of scientific information, which will empower them to make more informed decisions when scientific claims and data are involved (Colburn. 2004; Lederman. 1999). Additionally, the inclusion of the NOS in science teaching enhances the learning of science content, interest in science and decision making (McComas; Clough; & Almazroa. 2000). On the other hand, mistaken ideas of science likely affect students' attitudes toward science and learning in science classes. (Clough; & Olson. 2004). It also enhances teachers' changing views of teaching of science. Teachers who have a contemporary view of the NOS would be most likely to make more use of inquiry-based or constructivist teaching approach (Lederman. 1998; McComas; et al. 2000).

For science educators the phrase "nature of science," is used to describe the intersection of issues addressed in the philosophy, history, sociology, and psychology of science as they apply to and potentially impact science teaching and learning (McComas; Clough; & Almazroa. 2000). Educators encourage science teachers to use inquiry process to teach science since it corresponds to an important aspect of the NOS. As described above, NOS blends various kinds of social science studies, then it need to explicitly teach student about these aspects. If secondary school students are expected to develop more

adequate conceptions of NOS, then, as any cognitive objective, this outcome should be planned for, explicitly taught, and assessed.

In Thailand, the Institute for the Promotion of Teaching Science and Technology (IPST), which has the responsibility for developing science standards documents and promoting teachers in the teaching of science, has advocated the inclusion of the NOS in science curriculum. The understanding of the NOS is recommended as an objective of learning science for basic education. The school science curriculum that includes ideas about NOS is *Strand 8: Nature of science and technology* (Basic Education Curriculum, A.D. 2001). This strand emphasizes the use by students of scientific process and scientific investigative mind to solve problems, know that most natural phenomena have definite patterns explainable and verifiable within the limitations of data and instrumentation during the period of investigation, and understand that science, technology and environment are interrelated (IPST. 2003).

It is commonly accepted that teachers are playing a vital role in developing students' understanding of the NOS. Teachers are required to have an adequate understanding of the NOS and know how to help students construct their understanding of the NOS (Lederman. 1992; AAAS. 1994; McComas; et al. 2000; Abd-El-Khalick; & Lederman. 2000).

Although the NOS has long been seen as an important component of Thai Science Curricula for more than 30 years (since B.E. 2518), not many research studies have investigated the development of teachers' pedagogical content knowledge (PCK) for NOS instruction in Thailand. There was some survey research which studied Thai teachers' understanding of the NOS 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 NOS. Because of limitations of survey research, the real situation of the relationship between teachers' understanding of the NOS and their classroom practice has not been well studied. Although teachers generally seem to have adequate conceptions of the NOS, the realistic picture of teachers' understanding and their teaching of the NOS in classroom context are still vague. Additionally, there is a lack of the

deep information needed to develop an in-service secondary school teachers' teaching of science program in this area because research in science education rarely focuses on studying teachers' understanding and teaching of the NOS in real classroom contexts. The development of Thai teachers' PCK for NOS instruction has not been explicitly studied in Thai science educational research.

From the pilot study using an open-ended questionnaire and interviews, this research has found that secondary school teachers already have some conceptions of the NOS. However, their understanding of the NOS was generally limited, simplistic, and unclear. Teachers could not clearly explain these concepts verbally and were inadequate in teaching the NOS. From observation, it seems that their teaching is not consistent with their understanding. The two most predominant activities encountered in science class were teachers' lecturing and teacher-guided student practice, accounting for nearly half of class time. From classroom observation, aspects of NOS were not evidently integrated in their teaching activities and also in their teaching plans. In some classes, teachers used some hands-on activities and exercises in student workbooks or work sheets purposefully to develop students' understanding of those scientific facts. The science process skills, scientific attitudes, and concepts of the NOS were rarely found being explicitly taught or emphasized. Finally, most of them felt that they did not clearly understand what NOS was and had low confidence to teach this topic. Thus, it is possible that teachers do not really understand how to teach science by conveying appropriate concepts of the NOS although they seem to appreciate the teaching approaches related to what science and scientific inquiry is. This may be the result of their unclear understanding of the NOS 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 NOS. This puts serious limitations on their abilities to plan and implement lessons that will help the students develop an image of science that goes beyond the familiar "body of knowledge".

In order to develop teachers' understanding and teaching of the NOS, it is important to emphasize developing teachers' pedagogical content knowledge for NOS instruction. This means teachers should have adequate understanding or conceptions of

various aspects of the NOS, as well as the knowledge of how to teach those aspects of the NOS effectively (Abd-El-Khalick; & Lederman. 2000; Akerson; & Abd-El-Khalick. 2003).

Therefore, this study aimed to produce a professional development program to improve teachers' understandings of the NOS and classroom practice. The professional development program advocated an explicit/ reflective approach to NOS in order to help teachers improve their understanding of NOS and their skills for how to explicitly teach NOS.

The research questions guiding the investigation are:

- (1) How do in-service teachers understand concepts of the NOS?
- (2) How do in-service teachers change (if any) their views about the NOS?
- (3) How do teachers generally address NOS in their teaching?
- (4) Do teachers improve their pedagogical knowledge related to NOS through three teaching sessions?
- (5) What are the possible sources or specific supports from the professional development program for improving their practice in teaching NOS?

Research Objectives

The main purpose of this study is to develop in-service secondary teachers' understanding of the NOS in both conception and instruction. The second aim is to propose and develop an effective professional development program for enhancing in-service secondary teachers on their understanding and the instruction of the NOS.

Significance of the Study

This research provided a professional development program for developing teachers' understanding of the NOS and developing in-service teachers to improve their NOS-specific pedagogical knowledge. It was anticipated that this program would effectively improve teachers' understanding and teaching of the NOS in their real classroom practice.

Even though this program was designed for use with the participants in this study, it can be adopted for use in various ways. 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.

Scope and delimitation of the study

Population

The population of this study consists of in-service science teachers who taught science for secondary students (key stage 3-4) during of the 2006 academic year and 1st semester of 2007. They were employed from Educational Area 1 of Saraburi Province.

Participants/Sample

Phase 1: Developing teachers' understanding of the NOS

The participants were 15 science teachers who taught science subjects (general science, biology, chemistry, physics or Earth science, astronomy and space) to secondary students. They were from three schools in Saraburi Province. Those schools were selected by convenience sampling. Fifteen science teachers in these schools were selected by volunteer sampling.

Phase 2: Developing teachers' practice for NOS instruction

Six science teachers who had been participated in phase 1 of the training program continued to participate in Phase 2. This group of teachers worked closely with the researcher. They were assigned to teaching the NOS in their real classroom setting. The three workshops in the second phase; however, were opened to the other participants from Phase 1 as well.

Variables

Independent variable: The use of professional development program on developing teachers' understanding of the NOS and their classroom practice

Dependent variables:

1. Teachers' understanding of the NOS
2. Teachers' instruction of the NOS

Definition of Terms

1. Nature of Science

The concepts of the NOS 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. Scientists' explanations about what happens in the world come partly from what they observe and partly from what they think
- b) Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.
- c) Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, prior knowledge, expectation and belief dictate what and how scientists conduct their work.
- 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) Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.
- f) Science is a human endeavor and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted, accepted, and utilized.

- 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) Scientific knowledge is basically empirical. Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. For most major ideas in science, there is experimental and observational confirmation
- 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.

2. Teaching Approach of the Nature of Science

Teaching of the NOS in this research refers to the teaching of science by integrating the NOS concepts and instructional approaches into science courses in order to develop learners' understanding of the NOS as well as scientific concepts, science process skills, and scientific attitudes. Teachers' teaching of the NOS can be varied in the range from using implicit approach to didactic approach and to explicit approach.

The implicit approaches for teaching the NOS 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 NOS nor explicitly point out and reflect concepts of the NOS that are conveyed during practical work.

The didactic approaches for teaching the NOS in this research refer to any instructional approaches for science including the way of integrating the NOS. However, this discussion is separated from the activities that students have been engaged in. The lessons are identified as concentrating on teaching science content and making a simple didactic explanation of certain aspects of the NOS.

The explicit approaches for teaching the NOS 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 NOS or explicitly point out and reflect concepts of the NOS that are conveyed during practical work.

3. Professional Development Program on Teaching NOS

Professional development program on teaching the NOS is a professional development program designed to enhance secondary science teachers' knowledge and pedagogy of NOS. This program comprised two main phases: 1) Developing teachers' understanding of NOS-consists of two workshops and 2) Developing teachers' pedagogical content knowledge for NOS instruction-consists of three workshops.

4. The Effectiveness of Professional Development Program

The effectiveness of professional development program means the quality of the program being evaluated using these criteria:

- a Teachers' understanding of the NOS after attending the professional development program are better than those before attending the program
- b Teachers use explicit/reflective approach to teaching the NOS
- c Students' understanding of the NOS

5. Teachers' Understanding of NOS

Understanding of the NOS in this research refers to the understanding of concepts. Teachers' understanding of the NOS in each particular concept can be varied in the range of traditional view, mixed view, to contemporary view and in range from inadequate to adequate conception.

To explore teachers' views of the NOS, this study used two questionnaires. The first one was 5-point Likert scale questionnaire. The second one was an open-ended questionnaire. After teachers completed the open-ended questionnaire, the researcher interviewed teachers about their response in order to elaborate on and/or justify their answers.

6. On-site Support

During the Phase 2, the researcher served as a mentor for participants, providing individualized on-site support as they implemented new strategies in their classrooms. These mentoring activities consisted of the following: (a) providing support to teachers in their endeavors to teach the NOS (b) observing teachers' efforts to implement

the NOS in their classrooms, and (c) debriefing and discussing teachers' efforts to implement change.

7. Reflective Writing

The reflective writing is the teachers' self-evaluation report. It was a reflective essay assessing and describing their own learning experiences accomplished while enrolled in the training program. It required teacher to think back on the lesson and considered the answers to questions, for example:

- What went well in this lesson? Why?
- What problems did I experience? Why?
- What could I have done differently?
- What did I learn from this experience that will help me in the future?

Theoretical Framework

Lederman, 1992 stated in his review that research related to the NOS falls into five related, but distinct, categories: 1) students' conception of the NOS; 2) teachers' conception of the NOS; 3) assessment of the NOS curricula and interventions; 4) relationships between teachers' conceptions of NOS, classroom practice, and students' conceptions of NOS, and 5) development and validation of the NOS assessment instruments (both quantitative and qualitative). In this research, the parts of how to enhance teachers' understanding of NOS and their teaching skills are studied. This study includes aspects of categories 2 and 4.

Previous research on primary science teachers' understandings of the NOS and their teachings has been conducted in the professional development program by Tepkanya Promkatkeaw (2007). Findings from the study have pointed to effective methods for developing teachers' views of the NOS and helping teachers teach the NOS. The following sections describe research in this area that was used to inform the design of the training program. Four guiding principles for construction the program were summarized and illustrated below.

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

The program should be designed to promote teachers' adequate understanding or conceptions of various aspects of the NOS and the knowledge of how to teach those aspects of the NOS 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 of NOS aspects.

The concepts of the NOS in which the participant teachers in this research should learn from the program are described on pages 6-7: "Definition of Term: The Nature of Science".

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

- Modeling strategies that reflect an understanding of the NOS;
- Addressing explicit and implicit views of the NOS portrayed in activities;
- Evaluating textbooks, teaching materials, and other curriculum materials for their accuracy in portraying the NOS;
- Modifying curriculum materials and activities so they more adequately portray the NOS;
- Implementing timely historical and contemporary science examples that effectively convey a more accurate portrayal of the NOS;
- Ensuring that students have several experiences when they are *doing* science, and then *reflecting* on the process and what it implies about the NOS;
- Self-evaluating classroom performance as it pertains to an accurate portrayal of the NOS;
- Integrating a variety of formative assessments to continually monitor students' conceptions of significant issues in the NOS.

2. The program should be constructed based on the 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 knew; how this knowledge could 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; & 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 evaluate 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.

3. 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.

Recent work indicates that an explicit/reflective approach, combined with classroom support, which emphasizes aspects of the NOS, is effective for in-service teachers in developing their own NOS conceptions and abilities to teach the NOS to their student (Abd-El-Khalick; & Akerson. 2004).

Teachers' cognitive development in the nature of science concepts can be encouraged effectively by the use of an explicit approach for teaching the NOS in the teacher development program. This explicit approach can enhance teachers' construction or reconstruction of their understanding of the NOS by their reflection on the activities in which they had engaged. These activities were the discussion about some aspects of the NOS arising from reading assignments, science stories, or historical case studies, and participation in open-ended inquiry, investigation, or other practical work (Nott; & Wellington. 1998; 2000).

4. 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' PCK for NOS instruction and their classroom practice.

Teachers' classroom practice in the NOS 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 NOS and PCK for NOS instruction can also be enhanced by the teacher considering and analyzing the science curriculum; planning the NOS 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. 2000; Bell; Lederman; & Abd-El-Khalick. 2000; Schwartz; & Lederman. 2002).

Research Hypotheses

The hypotheses of this study are:

1. Teachers' understanding of the NOS after attending the professional development program has more agreement with contemporary views than that before attending the program.
2. Teachers' understanding of the NOS after attending the professional development program shows improvement than that of before attending the professional development program.
3. Teachers' practice shows the improvement (shift from implicit or didactic approach to explicit and reflective approach) on teaching the NOS through three teaching sessions.

CHAPTER TWO

REVIEW OF THE LITERATURE

This chapter reviews the literature that is relevant to the research objectives and the circumstances in which they are explored. The literature review aims to identify the various exemplary perspectives of science education that can be used to explain: 1) Nature of science; 2) The nature of science in science education; 3) The nature of science teaching approach; 4) Questionnaires for assessing understanding of the nature of science; 5) The role of teacher to the nature of science instruction; 6) Improving teachers' pedagogical approaches for nature of science; 7) Designing professional development; and 8) Evaluating professional development.

Courses syllabus of the professional development program and an overview of the concepts and instructions of the NOS emphasized in are shown at the end of Chapter 2.

1. The Nature of Science

1.1 Definition of Nature of Science

The phrase “history and philosophy of science” (HPS) has been used to describe the interplay of disciplines that inform science education about the character of science itself. However, a more encompassing phrase to describe the scientific enterprise for science education is the “nature of science (NOS)” (McComas. 2000). As shown in Figure 1, 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 endeavors (Lederman. 1992).

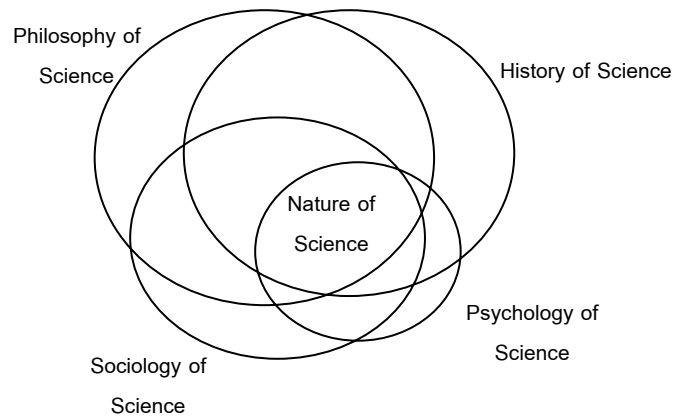


FIGURE 1 AN INTERSECTION OF SOCIAL STUDIES MAKING OF A DESCRIPTION OF THE NATURE OF SCIENCE

Source: McComas, W. F.; Clough M. P.; & Almazroa H. (2000). *The Nature of Science in Science Education Rationales and Strategies*. p. 50.

There is no one absolute definition of this term. The National Science Teachers Association (NSTA) noted that philosophers, historians, scientists, and science educators have not yet agreed on a single definition (NSTA. 1998). The conceptions of the NOS 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” (Lederman. 1998; Akerson; et al. 2000: 298). Additionally, there are various definitions of this term in the literature (AAAS. 1994; McComas; et al. 2000).

Lederman (1992) and Lederman et al. (1998: 331) referred to the NOS 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.

McComas et al. (2000: 4-5) provides a good overall description of the NOS in the following paragraph:

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 endeavors. Through multiple lenses, the nature of science describes how science functions.

Based on Lederman's definition, in this research the NOS 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.

1.2 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 NOS (Lederman. 1992; McComas; et al. 2000). By this promotion, the contemporary view of the NOS has been advocated extensively. Many researchers and educators argue for this contemporary view against the traditional view of the NOS for effective science instruction. They claim that teachers and students should construct their understanding of the contemporary view exclusive of the traditional view which is often stated as misconceptions (Hammerich. 2000; Haidar. 1999). In order to clarify these two opposing views, the philosophical backgrounds of these views need to be discussed.

1.2.1 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, 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. 2000). 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 hypothetical - deductive method. By these methods, scientific inquiry begins by observation and/or formulating and 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).

1.2.2 Contemporary View of the Nature of Science

The 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; & Tippins. 1993). From this point of view, scientific constructs, e.g. atoms, are "postulated entities" (Munby. 1983: 150) or "mental construct" (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 scientist, can be changed and replaced by new theories which have more substantial evidence (Hung. 1997; Haidar. 1999)

Constructivism claims development of scientific knowledge is "a set of socially negotiated understandings of the events and phenomena that comprise the experienced universe" (Tobin; & 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 guarantees 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; & Tippins. 1993; Haidar. 1999).

These two different perspectives on the NOS 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. 2000).

1.2.3 Some Other Misconceptions of the Nature of Science

There are other misconceptions which have no connection with these two philosophical perspectives. These misconceptions are held by teachers and students who view the NOS 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 e.g. theories, laws, experiments, hypotheses, observations, and inferences illustrate these misconceptions (McComas. 2000; 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 understanding of the NOS (Akerson; et al. 2000).

Generally, these two philosophical perspectives, traditional and contemporary views of science, are underpinning an individual's understanding of the NOS. Thus, the conceptions of the NOS can be categorized into three possible groups; based on traditional views, based on contemporary views, and based on mixture of traditional and contemporary views. Additionally, the conception of the NOS can also be categorized into misconception, naïve view, and appropriate conception of the NOS, for the conception which is not related to the philosophical perspectives (Haidar. 1999).

These definitions give criteria for this study for use in identifying participant teachers' understanding of the nature of science.

2. Nature of Science in Science Education

For science educators the phrase "nature of science," is used to describe the intersection of issues addressed by the philosophy, history, sociology, and psychology of science as they apply to and potentially impact science teaching and learning. As such, the NOS is a fundamental domain for guiding science educators in accurately portraying science to students.

2.1 The Value of Nature of Science for Teaching and Learning

Driver et al. (1996) have suggested five additional arguments supporting the inclusion of the NOS as a goal of science instruction. The arguments include the utilitarian view that “an understanding of the nature of science is necessary if people are to make sense of the science and manage the technological objects and processes they encounter...” (p. 16). This is related to the democratic view that people must understand the NOS “to make sense of socio-scientific issues and participate in the decision-making process” (p. 18) and the cultural argument that such understanding is necessary “in order to appreciate science as a major element of contemporary culture” (p. 19). Driver’s final justification for including the nature of science in science instruction is that it “supports successful learning of science content” (p. 20).

Many science educators and researchers claimed the importance of teaching and learning about the NOS 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 NOS also enhances students’ learning of science content, awareness of moral and ethical values, and decision - making (Driver; et al. 1996; McComas; et al. 2000). It also enhances teachers’ changing views of learning and teaching of Science. Teachers who have a contemporary view of the NOS would be most likely to make more use of inquiry - based or constructivist teaching (Lederman. 1998; McComas; et al. 2000).

2.2 The Nature of Science in International Science Curriculum

Current reform documents place a strong emphasis on students’ understandings of the NOS (AAAS. 1993; NRC. 1996). Interestingly, the importance of this educational outcome is not new and has been agreed upon as important by most scientists and science educators for the past 100 years (Lederman. 1992).

In United States, students need to understand that science reflects its history and is an ongoing, changing enterprise. The standards for the history and nature of science recommend the use of history in school science programs to clarify different aspects of scientific inquiry, the human aspects of science, and the role that science has played in the development of various cultures (NRC. 1996).

Science for all Americans lays out recommendations for what knowledge of the way science works is requisite for scientific literacy. That focuses on three principal subjects: the scientific world view, scientific methods of inquiry, and the nature of scientific enterprise. The following are some examples of the NOS aspects emphasized in this document: the world is understandable; scientific ideas are subject to change; scientific knowledge is durable; science cannot provide complete answers to all questions; science demands evidence, science is a blend of logic and imagination; and science is a complex social activity.

Science National Curriculum for England (National Curriculum Online. 2006: online) also includes ideas about science for all key stages. This strand called ideas and evidence. In key stage 4, students should be taught: how scientific ideas are presented, evaluated and disseminated [for example, by publication, review by other scientists]; how scientific controversies can arise from different ways of interpreting empirical evidence [for example, Darwin's theory of evolution]; ways in which scientific work may be affected by the contexts in which it takes place [for example, social, historical, moral and spiritual], and how these contexts may affect whether or not ideas are accepted; to consider the power and limitations of science in addressing industrial, social and environmental questions, including the kinds of questions science can and cannot answer, uncertainties in scientific knowledge and the ethical issues involved.

McComas, Clough and Almazroa (2000: 6-7) reviewed the NOS recommendations contained in eight international science education standards documents as shown below. Their recommendations show significant overlap.

- Scientific knowledge while durable has a tentative character.
- Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism.

- There is no one way to do science (therefore, there is no universal step-by-step scientific method)
- Science is an attempt to explain natural phenomena
- Laws and theories serve different roles in science; therefore students should note that theories do not become laws even with additional evidence
- People from all cultures contribute to science
- New knowledge must be reported clearly and openly
- Scientists require accurate record keeping, peer review and replicability
- Observations are theory-laden
- Scientists are creative
- The history of science reveals both an evolutionary and revolutionary character
- Science is part of social and cultural traditions
- Science and technology impact each other
- Scientific ideas are affected by their social & historical milieu

2.3 The Nature of Science in Thai Basic Education Curriculum, A.D. 2001

In Thailand, Science is the principal subject group in the basic education curriculum of AD 2001. Sub-strand 8: Nature of science and Technology is the one of eight subject groups in science learning. Standard Sc 8.1: The student should be able to use the scientific process and scientific mind in investigation, solve problems, know that most natural phenomena have definite patterns explainable and verifiable within the limitations of data and instrumentation during the period of investigation, understand that science, technology and environment are interrelated.

Standard Sc 8.1 in Sub-strand 8: Nature of Science and Technology is about learning process and it focuses on inquiry, problem solving, nature and limitation of science, attitude, moral and ethics. Expected learning outcomes for each year and semester are spelled out: student has opportunities to practice by variety of activities in all science subjects leading to knowledge and process to do science project that each student has to construct at least one project before finishing each level. IPST sets the standards for

learning at the basic level, the standards for learning at different levels and provides core subject matters for basic education.

Definition and Elements of the Nature of Science

IPST has identified the NOS 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 NOS concepts. Additionally, IPST recommends 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 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).

Visions, Aims, Objectives, and Outcomes for Learning of 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 about 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 document, this science curriculum also aims at developing students to be science literate and has at least four objectives of science education regarding the NOS. Nature of Science is for:

- understanding boundaries, nature, and limitations of science;
- developing thinking process and imagination, ability in solving problems and management, communication skills, and ability in making decisions;
- recognizing the relationship between science, technology, people, and the environment and their effects and impact on each other;

- being individuals who have scientific attitudes, morals, ethics, and values in using science and technology creatively (IPST. 2003: 4).

In attempting these aims and objectives, one new science content strand called “The Nature of Science and Technology” has been created. Learning outcomes (IPST. 2003: 36) have been explicitly set as:

Students should:

- understand the relationship between science, technology and society;
- understand boundaries and limitations of science;
- achieve scientific attitudes, integrity, values and desirable attributes;
- achieve skills in using scientific inquiry and problem-solving processes.

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).

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).

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.

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.

2.4 The Nature of Science Conceptual Scheme in this study

It can be concluded that the elements of the Nature of Science which should be content of the NOS for teachers and students teaching contexts consist of:

- Science is the seeking of approximate answers to questions about nature. It is a process that assists in making sense of the world. Scientists' explanations about what happens in the world come partly from what they observe and partly from what they think
- Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.
- Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, prior knowledge, expectation and belief dictate what and how scientists conduct their work.
- 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.
- Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.

- Science is a human endeavor and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted, accepted, and utilized.

- 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.

- Scientific knowledge is empirical basis. Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models for most major ideas in science, there is experimental and observational confirmation

- 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.

3. The Nature of Science Teaching Approach

3.1 Inquiry as a context for learning NOS

From a situated cognition perspective, knowledge is linked to activity and the situation under which the knowledge is acquired. Thus, scientific inquiry may provide a viable context for discussion and reflection within which learners can develop the NOS conceptions (NRC. 1996). Different approaches to contextualizing the NOS within inquiry have varied in effectiveness. It is important to note that there is necessarily an overlap between the targeted aspects of the NOS and aspects of scientific inquiry. However, even though the NOS and scientific inquiry are interrelated concepts, they each need to be addressed explicitly. An understanding of one does not ensure an understanding of the other. The distinctions between the NOS and scientific inquiry (or science process) need to keep clear. Conflation leads to reliance on implicit messages to teach one or the other.

As both a way to teach the NOS and to achieve scientific literacy, reform documents urge teachers to engage their pupils in authentic research activities. The

National Science Education Standards (1996) includes two content standards that are specific to this study. The first is Science as Inquiry, which states that pupils should understand the nature of science as inquiry and requires that pupils combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. The Content Standards call for pupils to know and understand the history and nature of science as a way to clarify different aspects of scientific inquiry, the human aspects of science, and the role that science has played in the development of various cultures. It can be argued that if these standards are to be met, teachers need to understand this content and know the teaching methods that facilitate the learning of this knowledge. Few science teachers possess adequate conceptions of the nature of science (Lederman. 1992) and their teaching does not reflect science as done by scientists. Accordingly, their pupils learn science as pre-packaged and delivered knowledge (Lederman. 1992).

In general, NOS-specific pedagogical approaches can be categorized into either implicit or explicit and reflective. The implicit approach proposes that by engaging learners in inquiry-based activities, or exposing learners to episodes of history of science, they will also come to understand the NOS. With respect to an inquiry-based approach, it is assumed that learners may be able to understand epistemological meanings behind “doing science”. For example, through experiences of generating data, using those data to explain certain problems, and comparing their explanations with a scientific theory, learners are expected to develop an understanding of how scientific theories change. Research adopting this approach has provided little evidence for its effectiveness on learning of the NOS (Khishfe; & Abd-El-Khalick. 2002). The historical approach suggests the incorporation of history of science in science teaching is essential in order for learners to enhance their understandings of the NOS. History of science has been viewed as having a significant role in learning the NOS. The approach assumes that learners will discern aspects of the NOS embedded in historical episodes. Evidence concerning the effectiveness of the historical approach (Abd-El-Khalick; & Lederman. 2000) is, at best, inconclusive. Therefore, research using an implicit approach indicates that it is unlikely that learners can learn what teachers

do not intentionally teach by simply engaging in inquiry-based activities or historical episodes.

3.2 Explicit Approach

The explicit approach recommends that the goal of improving learners' views of the NOS 'should be planned for instead of being anticipated as a side effect or secondary product of varying approaches to science teaching (Akindehin. 1988: 73). Like any other cognitive learning outcomes, the NOS should be specific and tangible content that teachers intentionally plan to teach and assess in classroom instruction. Recent reform documents also have advocated the NOS as 'content' that K-12 students should possess for scientific literacy (AAAS. 1993; NRC. 1996). It should be noted that the explicit approach does not refer to a didactic strategy. Rather, the explicit approach to instruction is comprised of NOS-relevant questioning, discussions, and guided reflection to help learners understand target aspects of the NOS, Therefore, in this study the authors use an 'explicit and reflective' approach to distinguish from an explicit but not reflective teaching. Empirical support has been obtained for the effectiveness of the explicit and reflective approach in enhancing learners' understanding of the NOS (e.g., Akerson; Abd-El-Khalick; & Lederman. 2000; Khishfe; & Abd-El-Khalick. 2002).

4. Questionnaires for Assessing Understanding of the Nature of Science

During the past 40 years, more than 20 standardized, convergent paper-and-pencil instruments have been developed to assess understanding of the NOS. Recently, the standardized instruments have been criticized on the basis of their questionable validity (Lederman; et al. 1998). For example, the NOS items on questionnaires tend to be more ambiguous than learning environment items, and this results in a greater chance of incongruence between what the developers mean and what the respondents perceive and interpret. Also, as mentioned earlier, NOS instruments reflect their developers' NOS views and biases (Lederman; et al. 1998) and, because they are forced-choice instruments, they can impose the developers' views on respondents. Thus "the views that ended up being ascribed to respondents were more likely an artifact of the instrument in use than a faithful representation of the respondents' conceptions of the NOS" (Lederman; et al. 2002: 502).

Consequently, throughout the 1990s, there were developed several free-choice or open-ended response questionnaires, some with the recommendation of conducting interviews with respondents to verify and clarify answers. Nature of science research moved away from quantitative studies and embraced highly interpretive qualitative studies involving small sample sizes.

Studies related to teachers' understandings of the NOS that used the instruments are described below.

Views of Nature of Science-Form C (VNOS-C)

Views of Nature of Science-Form C (Lederm; et al. 2002) is an open-ended response questionnaire based on a Kuhnian (1962) philosophy of science, and developed with a postmodern interpretive framework in mind. Its aim is to reveal participants' views on various aspects of NOS for the purpose of informing the teaching and learning of NOS. The developers state the VNOS should not be used to label learners' views as adequate or inadequate, or to sum their NOS understandings into a numerical score. The VNOS is based on eight 'aspects' of NOS that are considered less contentious, attainable, and relevant to the daily lives of K-16 students and teachers (Abd-El-Khalick; et al. 1998; Lederman; et al. 1992). These aspects and their corresponding objectives include the ideas that scientific knowledge is:

1. Tentative
2. Empirically-based
3. Subjective or theory-laden
4. The product of both observation and inferences
5. Dependent on creativity and imagination
6. Socially and culturally embedded
7. Based on a foundation of theories and laws
8. Not derived from a universal, recipe-like method for doing science

The developers stress that these aspects are interrelated and cannot be considered apart from the others, and that there is not a one-to-one correspondence between an item on the questionnaire and a target of NOS aspect listed above (Lederman; et al. 2002; Schwartz; et al. 2004). The items consist of 10 open-ended questions,

administered in a pretest-posttest design. Developers also emphatically say that interviews must be conducted with a subsample (15-20%) in order to probe respondents' views further and clarify or expand upon understandings. Validity was established by comparing participants' NOS profiles generated from their written responses with their corresponding interview transcripts (Abd-El-Khalick. 2001). Comparisons indicated congruence between the two formats.

5. The Role of the Teacher in the Nature of Science Instruction

Despite the pervasive and critical role of curricula, evidence is clear and substantial that teachers are the most influential factor in educational change (Duffee; & Aikenhead. 1992) and those teachers' male exemplary programs.

Teacher translates the written curriculum into a form ready for classroom application and decides what, how and why to learn. As Eisner (1985: 59) writes, "In the final analysis, what teachers do in the classroom and what students experience define the educational process." In fact, curriculum has been claimed to constitute only five percent of the variance in students' learning (Welch. 1979), while science teachers' beliefs, knowledge, and practices represent the bulk of what the science instructional experience is for students (Smith. 1980).

5.1 Role of teacher's verbal behaviors 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 NOS (McComas; et al. 2000).

In summary, the NOS could be taught based on the constructivist view of learning. Teachers have a role to elicit students' conceptions of the NOS and facilitate movement from students' misconceptions or naïve views toward the correct scientific view. As well as appreciating the importance of the NOS 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 NOS instruction which are included in Clough's points of concern.

1. Modeling behaviors, strategies, and language that reflect an understanding of the NOS. For example, accurate usage of significant language in the social studies of science affects students' perceptions of the NOS.
2. Addressing explicit and implicit view(s) of the NOS portrayed in activities (lab or otherwise).
3. Evaluating textbooks, audiovisual materials, and other curriculum materials for their accuracy in portraying the NOS.
4. Modifying curriculum materials and activities so they more adequately portray the NOS.
5. Implementing timely historical examples that effectively convey a more accurate portrayal of the NOS.
6. Ensuring that students have several experiences where they are *doing science*, and then *reflecting* on the process and what it implies about the NOS.
7. Self-evaluating classroom performance as it pertains to an accurate portrayal of the NOS.
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 NOS (Clough. 1997: 200).

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

5.2 Teacher understanding and their instruction of the Nature of Science

5.2.1 Teacher's Conceptions of the Nature of Science

Both pre-service and in-service science teachers normally have similar views regarding the NOS (Rubba; & Harkness. 1993; Haidar. 1999; Tairab. 2001). In general, they hold a view of science that is positivist, naïve realist, authoritative, and supports scientism (Rubba; & Harkness. 1993; Abell; & Smith. 1994; Tobin; & McRobbie.

1997). 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; & 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 NOS (Pomeroy. 1993; Haidar. 1999; Tsai. 2002).

5.2.2 Teachers' Instruction of the Nature of Science

The instruction of the NOS can be categorized into three major groups according to Akerson and Abd-El-Khalick's coding scheme (2003: 1032). Level 1 NOS instruction refers to "missed opportunities" to teach some aspects of the NOS. This level does not refer to teacher 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 NOS. Level 2 NOS instruction refers to didactic addressing some aspects of the NOS in the teaching. It includes some instructional activities with "isolated statements" which are consisted with some aspect of the NOS, such as inquiry activities, but students do not have opportunities to consider or reflect explicitly on those aspects of the NOS. Level 3 NOS instruction refers to explicitly addressing some aspects of the NOS in the instruction. Teachers use some activities which explicitly engage students in constructing their understanding of the nature of science.

Based on this scheme, various researchers found that teachers generally teach the NOS science only at Level 1 and 2. Tobin and McRobbie (1997: 366-367) studied on high school chemistry teacher teaching the NOS. They found that although this teacher had adequate conceptions of the NOS, 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) studies the teaching of five high school biology teachers. 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 inference. However, he found that these two teachers did not purposefully emphasize concepts of the NOS 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 NOS were too abstract for her students to learn effectively.

For the beginning teachers, Lederman found that even when teachers were interested in addressing the NOS in their teaching, the NOS was not obvious in their classroom practices because of the classroom management factor. For intern student teachers, Eick (2006: 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 laboratory practices to help students learn scientific concepts. Some frequently-used 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 Level 2 NOS instruction, even though she had informed views and proposed to teach some aspects of the NOS. They found that this teacher believed that "she was teaching about the NOS by providing students with opportunities to do science: that is, engaging them in activities and process similar to those engaged by scientists". The general activities which this elementary teacher used in teaching science were using non-fiction children's books for reading curriculum; setting student reading science content and time for scheduling doing for science 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.

6. Improving Teachers' Pedagogical Approaches for the Nature of Science

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

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

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

Recent research on improving teachers' abilities to teach the NOS has been carried out mostly with pre-service teachers. Abd-El-Khalick, Bell, and Lederman (1998) investigated the relationship between pre-service teachers' understanding and their teaching of the NOS. Spanning two semesters, two science methods courses, a science pedagogy course, and a science field-based internship heavily emphasized the NOS and how to teach the NOS. During the following semester, participants completed a full-time internship in a school setting. Participants' understandings of the NOS assessed at the end of coursework were compared with their teaching practice in the student teaching internship. The data analyses showed that participants possessed adequate understandings of the NOS, but few explicitly addressed the NOS in their teaching. Although many participants claimed that they taught the NOS, their pedagogical approach to teaching the NOS was simply to involve students in doing science without any attempt to discuss about the NOS. They did not recognize their implicit teaching which was not very effective.

In a follow-up study, Bell, Lederman, and Abd-El-Khalick (2000) hypothesized that the lack of pre-service teachers' pedagogical knowledge for teaching the NOS might be caused by the simultaneous exposure of pre-service teachers to learning the NOS and how to teach the NOS in methods courses. Therefore, the intervention was to separate teaching NOS from instruction on how to teach the NOS to secondary students. The results indicated that participants were better than those in the prior research with respect to the teaching of the NOS in an explicit and reflective manner. The participants in the study taught the NOS more frequently in the student teaching internship and knew the importance of explicit and reflective instruction. However, the majority neither included the NOS objectives in their lessons nor attempted to assess students' understandings of the NOS.

In integrating the NOS with science lessons, teachers' subject matter knowledge appears to be an important factor. In a case study conducted by Schwartz and Lederman (2002) the pre-service teacher, who had an extensive science background was better able to implement the NOS instruction than the other participant with limited subject matter knowledge. However, he also had difficulty fitting NOS into the context of unfamiliar science content, even though he was successful in integrating explicit and reflective the NOS teaching into familiar science content teaching.

A similar pattern regarding the role of subject matter knowledge was found in the study by Akerson and Abd-El-Khalick (2003), which was conducted with an in-service elementary teacher. The data analysis indicated that teacher held informed views of the NOS and strong intent to teach the NOS in the lesson. However, the teaching of the NOS was initially restricted to implicit approaches of just involving students in activities of "doing science" without any debriefing related to the NOS. In content-specific lessons (e.g. a model of the inside of the earth), she could not address the NOS in the lesson because she lacked the necessary content knowledge. Since she did not know what the evidence is for the model of the inside of the earth, she could not highlight the fact that scientists also could not see the inside of the earth, so they needed to infer and develop a model of that based on collected data. With several supports including model lessons by the researchers, teacher was able to use explicit approaches for the NOS.

The existing literature implies that science educators should specifically help teachers learn how to teach the NOS. The efforts include helping teachers shift their pedagogical approaches of teaching the NOS from implicit to explicit and reflective, learn how to assess their students' understandings of the NOS, and improve their abilities to fit NOS into science content lessons. In establishing in-depth knowledge of how to help teachers develop knowledge in NOS instruction, some work is still left to be done. First, most research on enhancing teachers' instruction of NOS has been done with pre-service teachers. More empirical research is needed with in-service teachers, since experienced teachers are different from pre-service teachers in pedagogical and subject matter knowledge. It is still unknown whether general findings about teaching NOS with pre-service teachers would be similarly shown in the context of in-service teachers' instruction of NOS. Second, it is essential that we examine the ways teachers fit NOS into their lessons. Little research has been conducted on what lesson contexts teachers feel comfortable to address NOS and in what contexts they do not.

However, the discrepancy between a teachers' understanding of the NOS and classroom practice has been consistently noted (e.g., Abd-El-Khalick; Bell; & Lederman. 1998; Brickhouse. 1990; Lederman. 1999). The assumption that teachers' knowledge of NOS is directly and necessarily conveyed to their students through classroom teaching lacks empirical support. Teachers' understanding of the NOS appears to be essential, but not sufficient, for translating their understanding into science teaching. Teachers who have an understanding of the NOS consistent with reform documents (AAAS. 1993; NRC. 1996) generally do not attempt to teach any aspects of the NOS explicitly or adopt inappropriate approaches for teaching the NOS (e.g., didactic approaches). The lists of constraints that potentially impede teaching of the NOS have been documented in recent literature (e.g. Bell; Lederman; & Abd-El-Khalick. 2000; Lederman; et al. 2001). Those constraints, in general, can be divided into two groups. One group includes factors that inhibit teachers' initiation of the NOS instruction such as pressure to cover content (Duschl; & Wright. 1989), perception of the NOS as less significant than other cognitive outcomes such as science content and processes (Abd-El-Khalick; et al. 1998), and instructional intention to teach the NOS (Lederman. 1999). The other consists of factors that impede explicit and reflective

NOS instruction, such as confusion between the NOS and science processes and lack of knowledge related to pedagogical approaches for the NOS (Abd-El-Khalick. 1998) and lack of subject matter knowledge (Schwartz; & Lederman. 2002).

One of the factors that facilitates or impedes teaching of the NOS is knowledge of NOS-specific pedagogical approaches. Although a teacher may have an adequate understanding of the NOS, knowledge of how to teach the NOS is necessarily required for the translation of this knowledge into classroom practice (Akerson; & Abd-El-Khalick. 2003; Schwartz; & Lederman. 2002). However, pedagogical knowledge of how to explicitly and reflectively address the NOS in classroom practice has not been the main focus of much research. Indeed, the majority of research on helping teachers' pedagogical knowledge for NOS has been conducted in the context of pre-service education and not with in-service teachers.

Four approaches to incorporating the NOS in science teacher education programs are frequently suggested (McComas; Clough; & Almazroa. 2000). Each of the four approaches has its own strengths and limitations and these are discussed below. One approach, where the NOS instruction is blended into methods classes, is most often applicable in the pre-service environment. Of course, some programs offer an advanced science methods course for experienced teachers, so the first approach to incorporating the NOS may also work for in-service teachers. The other three strategies may, with modifications, be used in either the pre-service domain or applied in general science instruction or science teacher education. Regardless whether one particular approach or a combination of approaches is used, several questions remain. These include the minimal amount of the NOS content needed by science teachers, who should teach such courses, and whether they should be required for both undergraduate and graduate students.

Nature of Science in Methods Courses

In this strategy, the content and pedagogical strategies of the NOS are communicated within a science teaching method course.

Advantages to the NOS in Methods Courses

The central advantage here is that nature of science content is discussed in an environment where the curriculum and pedagogical connections can be immediately

discussed. In this fashion, both the nature of science content, a rationale for its inclusion in science teaching, and the strategies for teaching that content will be conveyed to prospective science teachers. In addition, because practicum experiences should be tied to method course, students have the needed opportunities to put these strategies into action with students in schools. In addition, students (and perhaps other education faculty members) may be more receptive to the unfamiliar topics within the nature of science by encountering them with familiar faculty discussing familiar and applicable topics. Finally, this approach may facilitate discussions of the parallels between the development of science itself and the learning of science.

Disadvantages to the NOS in Methods Courses

The disadvantages associated with blending the NOS with methods include the possibility that other topics may be neglected or that the NOS itself may get less than adequate treatment given the many other issues needing attention in methods courses. Depending on the skill and knowledge of the instructor, the suggested NOS teaching methods may illustrate how to apply some NOS concepts, but miss other fundamental ideas and their integration with science content.

Nature of Science in Science Content Classes

This approach requires that significant attention to relevant the NOS issues be intertwined with the teaching of science content. In the pre-college environment this approach may be most strongly recommended, but in the college domain, pre-service science teachers may have problems deriving teaching strategies from pure NOS content.

Advantages to the NOS in Science Content Classes

One of the advantages to this approach is that students can see the application of the NOS in context, thus legitimizing the NOS as a useful domain. Instructors who take such an approach may cause change in the educational infrastructure itself by encouraging other instructors to include the NOS elements in their classes. Moreover, students in the class who are interested in the education have explicit modeling to draw from when designing instruction.

Disadvantages to NOS in Science Content Classes

Central among the disadvantages for this approach is the fact that science faculty members may not know how to discuss the NOS issues. Also, in the college environment, methods students learning about the NOS in their science classes may not receive useful strategies enabling them to share nature of science content with their own students. The critical challenge that remains is the question of who will provide science teachers with specific strategies permitting them to integrate NOS in their classes.

Teachers as Scientists

In this strategy, teachers of the NOS should have had some authentic experience actually *doing* science so that they can talk with some authority about how science is done.

Advantages to the Teachers as Scientists Approach

The advantage of this plan is that if individuals learn about the NOS by doing scientific research, those participating could speak with authority and enthusiasm about the NOS from first-hand experience. Another advantage is that those who have had such experiences would be more able to guide students in pursuing their own research and science fair projects.

Disadvantages to the Teachers as Scientists Approach

The primary disadvantage to this plan is found in the assumption that those who do science learn enough about the NOS to communicate it accurately. Research experience confers no guarantee that NOS knowledge is assimilated simply through working in a laboratory. In addition, the necessary strategies to translate the NOS content into classroom practice are missing.

Formal Courses or Units of Study in the Nature of Science

This plan would have science teachers learn about the NOS in a discrete unit of study or in a course taught by a science educator. In higher education, some might argue against a specific course focusing on the NOS for science teachers on the grounds that most major universities already provide formal history and philosophy of science courses taught by experts in those fields. Unfortunately, such courses tend to be abstract examinations of science usually from a highly theoretical and prescriptive perspective

commonly focusing primarily on a specific science discipline replete with symbolic logic and somewhat arcane (at least for the needs of science teaching) debates. While such courses are recommended for majors in those fields, and perhaps as continuing education for science teachers, the highly focused content is unlikely to be useful to the uninitiated science student or education major.

Advantages to Formal the NOS Courses

A specific NOS course or unit of study would guarantee that students see the fruitful connections between history, philosophy, sociology and psychology of science, not as a prescriptive endeavor within one science discipline, but as an authentic description of how science is practiced generally. If such a course were taught by a science educator, experiences in the course would likely be tailored to the needs of practicing science teachers. In addition, discrete courses could be implemented without revising other aspects of the education curriculum.

Disadvantages to Formal the NOS Courses

Specific courses invariably require additional time that may impact other useful courses thus prolonging the time needed to complete a degree or certification program. Also, a discrete NOS course may be disconnected from science content possibly diluting its relevance. Finally, if the course involves science teachers then it is vital that such courses connect to problems of teaching the NOS.

Lederman and Lederman (2000) introduce a set of activities designed to model an explicit approach to teaching crucial aspects of the NOS. These activities have been successfully used with students and science teachers. Science educators and science teachers can use the following activities to convey to students and pre-service or in-service teachers adequate notions of the NOS. Science educators can use these activities in either science content or science method courses. The following activities are presented in a nature of science unit or can be infused throughout a science content course of study. The activities are grouped in three sections relative to important aspects of the NOS. These sections include observation versus inference, creativity, and tentativeness, subjectivity and social and cultural context in science, and black-box activities.

Section 1: The following activities are designed to help students make the crucial distinction between observation and inference, and appreciate the tentativeness of scientific knowledge and the role of creativity in science.

'Tricky Tracks!' conveys to students the message that every idea counts irrespective of it being the 'correct' answer. Students completing this activity will gain experience in distinguishing between observation and inference and realizing that, based on the same set of evidence (observation, or data), several answers to the same question may be equally valid.

Other activities in this section are *the hole picture*, and *real fossils, real science*,

Section 2: Subjectivity and social and cultural context. Below are some example activities:

That's Part of Life,

Young? Old?,

The Aging President

Section 3: Black-box activities: Black-box activities provide students with challenges similar to those of encountered by scientists. Some examples of black-box activities are shown below:

The Tube,

The Hypothesis Box,

The Cans,

The Water-Making Machine,

The Cube Activity

7. Designing Professional Development

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' pedagogical content knowledge (PCK) for NOS instruction and classroom practice (Akerson; & 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 evaluate their teaching competence and clarify any problematic aspect of their teaching within 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; & 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; & Gilbert. 1994: 492). Additionally, teachers should appreciate the social communication and interaction as important for teacher development process and seek to initiate this collaboration further than only responding to

“a facilitator-initiated activity” (Bell; & 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.

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

Teachers’ cognitive development in the NOS conceptions can be promoted effectively by the use of an explicit approach for teaching the NOS in the teacher development program (Abd-El-Khalick; & Lederman. 2000). This approach can provide teachers with conceptual tools for eliciting and clarifying their existing conceptions of the NOS such as engaging in critical incident activity and the NOS profile activity (Nott; & Wellington. 1998; 2000). This explicit approach can enhance teachers’ construction or reconstruction of their understanding of the NOS by their reflection on the activities they have engaged in, such as discussion about some aspects of the NOS 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 NOS (Abd-El-Khalick; & Askerson. 2004).

Teachers’ classroom practice in the NOS 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 NOS and PCK of NOS instruction can also be enhanced by the teacher considering and analyzing the science curriculum; planning the NOS lessons for their 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 NOS instructional materials and resources for supporting teachers' instruction (Clough. 1998; Bell; Lederman; & Abd-El-Khalic. 2000; Schwartz; & Lederman. 2002).

Additionally, Abd-El-Khalick, Bell, and Lederman (1998: 432) have suggested that the effective teacher development program, specifically for the NOS instruction should emphasize four main aspects. The first aspect is to develop teachers' "understanding of the rationale behind and a comprehension of, the importance". The second is to give teachers much more extensive experience in teaching and assessing the NOS 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 NOS". This teaching experience should be planned opportunities for teachers to engage in, rather than leave it 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 explicit teaching the NOS. Teachers should be encouraged to oppose the ideas that "the NOS can be taught implicitly through student's participation in science activities".

In conclusion, a program for in-service teacher professional development on the NOS conceptions and instructions should be constructed based on the social constructivism. To guarantee the effectiveness of the program, a teacher development should emphasize the explicit approaches for the NOS instruction to serve as 'conceptual tools' for teachers' eliciting and clarifying their existing conceptions as well as a reconstruction of their conceptions of the nature of science. The modeling 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' PCK for instruction and their classroom practice. The design of activities with a teacher professional development program for the NOS instruction should be considered based on four specific aspects of developing teachers' understanding of the NOS instruction. These

aspects are developing teachers' understanding of rationale behind the teaching of the NOS; giving teachers' extensive experience in teaching and assessing the NOS; giving teachers' the supports in the field experiences; and developing teachers' intention to teach the NOS explicitly.

Loucks-Horsley et al. (2003) suggest the strategies for professional learning. They describe 18 different teacher learning strategies clustered around six categories: aligning and implementing curriculum, collaborative structures, examining teaching and learning, immersion experiences, practicing teaching, and vehicles and mechanisms. (see Table 1) A professional development program can be made up of multiple strategies offered simultaneously to different groups of teachers to meet their different needs or accommodate varied learning styles. For example, novice teachers might benefit from an inquiry immersion experience followed by mentoring. More expert teachers might follow up on the immersion experience with an action research project to study how students learn through inquiry. The strategies within a cluster share common underlying assumptions about teaching, learning, and professional development. Therefore, the clusters provide a framework for organizing the strategies and considering their selection and use.

TABLE 1 EIGHTEEN STRATEGIES FOR PROFESSIONAL LEARNING

<p>Aligning and implementing curriculum</p> <ul style="list-style-type: none"> • Curriculum alignment and instructional materials selection • Curriculum implementation • Curriculum replacement units <p>Collaborative structure</p> <ul style="list-style-type: none"> • Partnerships with scientists and mathematicians in business, industry and universities • Professional networks • Study groups <p>Examining teaching and learning</p> <ul style="list-style-type: none"> • Action research • Case discussions • Examining student work and thinking, and scoring assessment • Lesson study <p>Immersion experiences</p> <ul style="list-style-type: none"> • Immersion in inquiry in science and problem solving in mathematics • Immersion into the world of scientists and mathematics <p>Practicing teaching</p> <ul style="list-style-type: none"> • Coaching • Demonstration lessons • Mentoring <p>Vehicles and mechanisms</p> <ul style="list-style-type: none"> • Developing professional developers • Technology for professional development • Workshops, institutes, courses, and seminars

Source: Loucks-Horsley, Susan; et al. (2003). *Designing Professional Development for Teachers of Science and Mathematics*. p.113.

Professional development is more than offering isolated strategies. Every program, initiative, and professional development plan uses a variety of strategies in combination with one another to form a unique design. Each strategy is one piece of the puzzle, and how a designer fits strategies together depends on his or her particular circumstances. The professional development designer's challenge is to assemble a combination of learning activities that best meets the designer's specific goals and context.

From work with professional developers in science, they identified four interconnected outcomes that often drive professional development designs in science education:

- Increasing science
- Increasing pedagogical content knowledge
- Building a professional learning community
- Developing leadership

If we are working to promote these four outcomes, as many are, it is easy to see that one strategy will not be sufficient. Instead, the designer combines different strategies to address the different outcomes, with some strategies addressing more than one outcome. Increasing teachers' content knowledge is often best accomplished by immersing teachers in content as learners themselves. This can be accomplished through the immersion strategies, through partnerships, and in workshops/ institutes. But learning content alone will not lead to changes in teaching, so designers must build in opportunities for teachers to put the content they learn into the context of teaching and provide opportunities to develop pedagogical content knowledge. This is accomplished through different strategies, such as examining student work, case discussions, curriculum work, and lesson study. Engaging in such collegial arrangements helps to address the third outcome - building a professional learning community, which can also be developed through teachers' participation in lesson study, demonstration lessons, and study groups. The final outcome is often addressed through the use of the developing professional developer's strategy.

In addition to using the intended outcomes of a professional development program to guide the selection of strategies, another guide is knowing the purpose each strategy's

best addresses and matching it to the needs of participating teachers. Different strategies can be more appropriate for people depending on where they are in the change process. At the beginning of the process, teachers need concrete information and “how to” advice. Later they want ways to collaborate with others and assess impact.

For example, some strategies are more appropriate for building knowledge (e.g., workshops/ institutes and partnerships), whereas others help teachers reflect on learning and teaching (e.g., action research, examining student work, and lesson study). The following are some different purposes for strategies:

- Strategies that focus on *developing awareness* are usually used during the beginning phases of a change, which call for introducing teachers to new approaches or content. The strategies are designed to raise awareness through the introduction of new information and to elicit thoughtful questioning on the part of the teachers concerning the new information. Examples of strategies that help to raise awareness include professional networks, demonstration lessons, and study groups.
- Strategies that focus on *building knowledge* provide opportunities for teachers to develop science and mathematics content knowledge and pedagogical content knowledge. Examples of strategies often used to build knowledge include case discussions, immersion experiences, workshops, technology for professional development, and partnerships with scientists or mathematics.
- Strategies that help teachers *translate new knowledge into practice* engage teachers in drawing on their knowledge base to plan instruction and improve their teaching. Examples of strategies often used to help teachers translate knowledge into practice include coaching, mentoring, curriculum implementation, and demonstration lessons.
- Strategies that focus on *practicing teaching* help teachers learn through the process of using a new approach, practice, or process with their students. As they practice new moves in their classrooms, they increase their understanding and their skills. Examples of strategies often used to practice

teaching are examining student work, lesson study, coaching, mentoring, and demonstration lessons.

- Strategies that provide opportunities to *reflect deeply on teaching and learning* engage teachers in examining their experiences in the classroom, assessing the impact of the changes they have made on their students, and thinking about ways to improve. These strategies also encourage teachers to reflect on others' practice, relating it to their own and generating ideas for improvement. Examples of strategies often used to help teachers reflect on their practice include action research, study groups, lesson study, case discussions, and examining student work.

8. Evaluating Professional Development

Guskey (2000) suggests the professional development evaluation model. The levels in this model for evaluating professional development are hierarchically arranged from simple to more complex. With each succeeding level, the process of gathering evaluation information is likely to require increased time and resources. More importantly, each higher level builds on the ones that come before. In other words, success at one level is necessary the source of success at the levels that follow. Following is a brief description of each of the five levels in the model, and their importance in the evaluation process. Included are some of the crucial questions addressed at each level, how that information can be gathered and how that information will be used. A summary of these issues is also presented in Table 2.

TABLE 2 CRITICAL LEVELS OF PROFESSIONAL DEVELOPMENT EVALUATION

Evaluation Level	What Questions are Addressed?	How will Information be Gathered?	How will Information be Used?
1 Participants' reactions	<ul style="list-style-type: none"> • Did they like it? • Was their time well spent? • Did the material make sense? • Will it be useful? • Was the leader knowledgeable and helpful? 	<ul style="list-style-type: none"> • Questionnaires administered at the end of the session • Focus group • Interviews • personal learning logs 	<ul style="list-style-type: none"> • To improve program design and delivery
2 Participants' learning	<ul style="list-style-type: none"> • Did participants acquire the intended knowledge and skills? 	<ul style="list-style-type: none"> • Paper-and-pencil test • Simulations and demonstrations • Participant reflections (oral and/or written) • Participant portfolios 	<ul style="list-style-type: none"> • To improve program content, format, and organization
3 Organization support and change	<ul style="list-style-type: none"> • What was the impact on the organization? • Did it affect organizational climate and procedures? • Was implementation advocated, facilitated, and supported? • Was the support public and overt? • Were problems addressed quickly and efficiently? 	<ul style="list-style-type: none"> • District and school records • Minutes from follow-up meetings • Questionnaires • Focus groups • Structured interviews with participants and school or district administrations • Participant portfolios 	<ul style="list-style-type: none"> • To document and improve organizational support • To inform future change efforts

TABLE 2 (continued)

Evaluation Level	What Questions are Addressed?	How will Information be Gathered?	How will Information be Used?
4 Participants' use of new knowledge and skills	<ul style="list-style-type: none"> • Were sufficient resources made available? • Were successes recognized and shared? • Did participants effectively apply the new knowledge and skills? 	<ul style="list-style-type: none"> • Questionnaires • Structured interviews with participants and their supervisors • Participant portfolios • Direct observations • Video- or audiotapes 	<ul style="list-style-type: none"> • To focus and improve all aspects of program design, implementation, and follow-up
5 Student learning outcomes	<ul style="list-style-type: none"> • What was the impact on student? • Did it affect student performance or achievement? • Did it influence students' physical or emotional well-being? • Are students more confident as learners? • Is student attendance improving? • Are dropouts decreasing? 	<ul style="list-style-type: none"> • Student records • School records • Questionnaires • Structured interviews with students, parents, teachers, and/or administrators • Participant portfolios 	<ul style="list-style-type: none"> • To demonstrate the overall impact of professional development.

Source: Guskey, Thomas R. (2000). *Evaluating Professional Development*. pp. 79-81.

Increasingly, evaluators are becoming partners with professional developers in a commitment to continuous improvement of programs and their results. Involvement is the key word here, through such activities as:

- Engaging program staff as well as participants in specifying and discussing desired outcomes and identifying and prioritizing evaluation questions
- Involving staff and participants in the design or review of instruments or procedures for assessing outcomes
- Sharing responsibility with staff and participants for collecting data
- Engaging staff in analyzing and interpreting data
- Sharing responsibility for reporting learning from evaluation with a variety of audiences using a variety of formats.

Each of these activities can contribute to staff and participant understanding of their own learning and that of others; of a variety of methods to assess important learning outcomes as well as interpret information gathered; of ways to specify and then to investigate the answers to important questions; and of how to communicate to a variety of audiences and develop arguments for new ways of acting.

Courses Syllabus of the Professional Development Program

Phase 1: Developing Teachers' Understanding of the Nature of Science

Workshop 1: As an introduction, the instructor briefly presented excerpts from the National Science Curriculum (2003) and Standards of Science and Technology Teacher (2002) to show the presence of the NOS goals in national documents.

The activities of science stories (e.g. understanding of the universe, Newton and falling objects) and contemporary science issues (e.g. global warming) were used as tools to initiate teachers' understanding about the NOS.

Workshop 2: The second workshop consisted of 1) introduction to philosophy of science; 2) a set of activities: the hole picture, tricky tracks, the cube and the tube; and 3) debriefing after finish two workshops of Phase 1 of the program.

Phase 2: Developing Teachers' Pedagogical Content Knowledge for the Nature of Science

Session 1 of Teaching of the NOS in Real Classroom Setting

Workshop 3: The activities are about looking at where the NOS fits in curriculum. Discuss summary and present characteristics of good science teaching approaches. Study model lesson plan and summarize the NOS concepts and characteristics of an explicit approach to teaching the NOS which is embedded in this lesson plan. Modifying existing curriculum and goal setting for teaching science.

Session 2 of Teaching of the NOS in Real Classroom Setting

Workshop 4: Present and discuss about their teaching and peer review. Design lesson plan which focuses on developing students' scientific concepts, the NOS concepts, science process skills and scientific attitudes.

Session 3 of Teaching of the NOS in Real Classroom Setting

Workshop 5: Present and discuss about their teaching and peer review. Debriefing/reflecting on Goals and Successes.

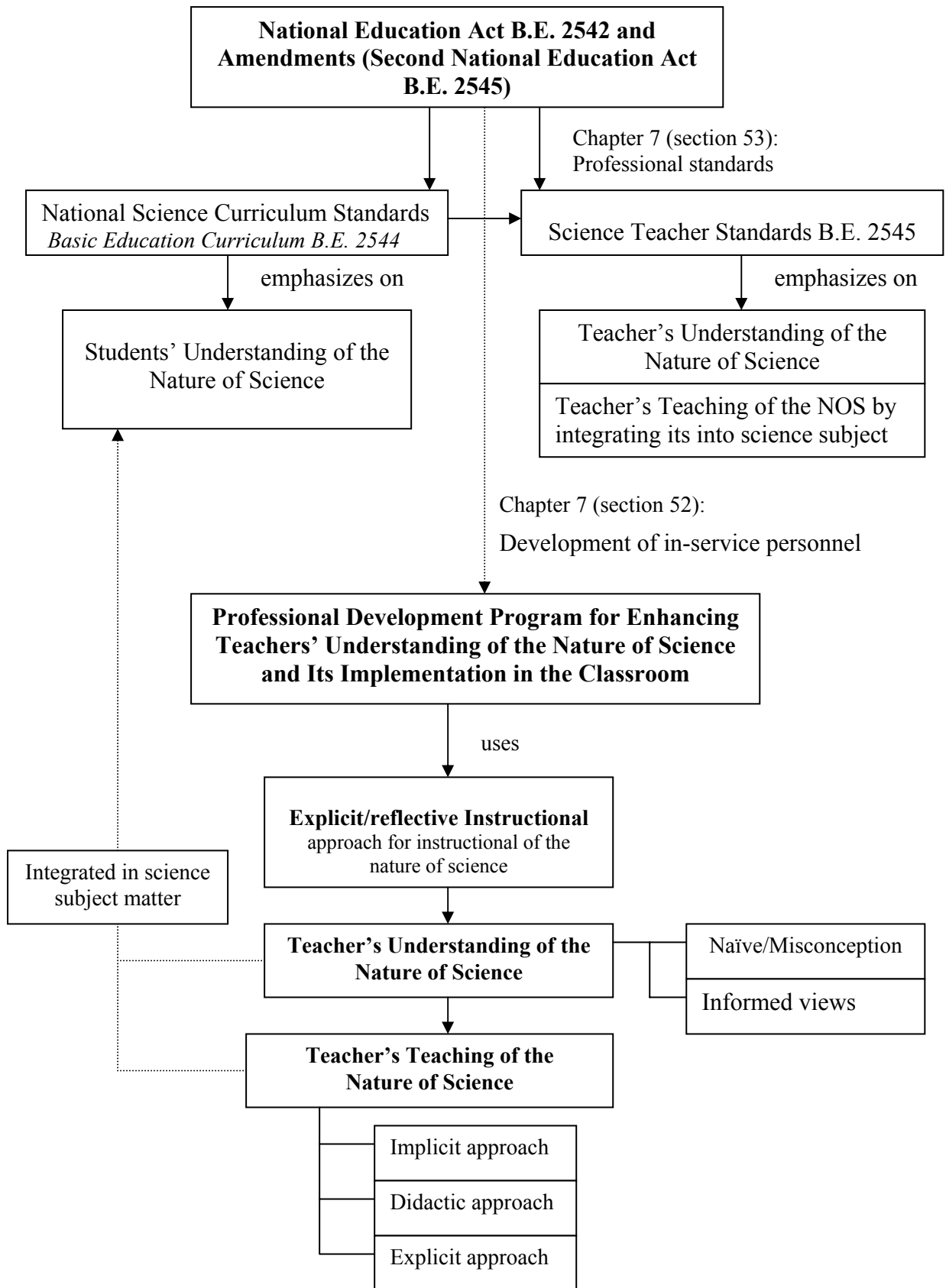


FIGURE 2 THE FRAMEWORK OF THE PROFESSIONAL DEVELOPMENT PROGRAM

CHAPTER 3

METHODOLOGY

The details of research techniques and instruments to be described are research participants, research phases and timeline, research instruments, data collection and data analysis procedures. The research methodology for this study consists of six stages to be presently described. However, this research methodology is iterative in nature, as it is necessary to continually refine professional development program in order to further improve science teachers.

Stage 1: Studying the Context and Problem about the Nature of Science
Teaching

Stage 2: Designing Professional Development

Stage 3: Draft of Professional Development Program Evaluation

Stage 4: Conducting a Pilot Study

Stage 5: Program Implementation

Stage 6: Program Evaluation after Implementation

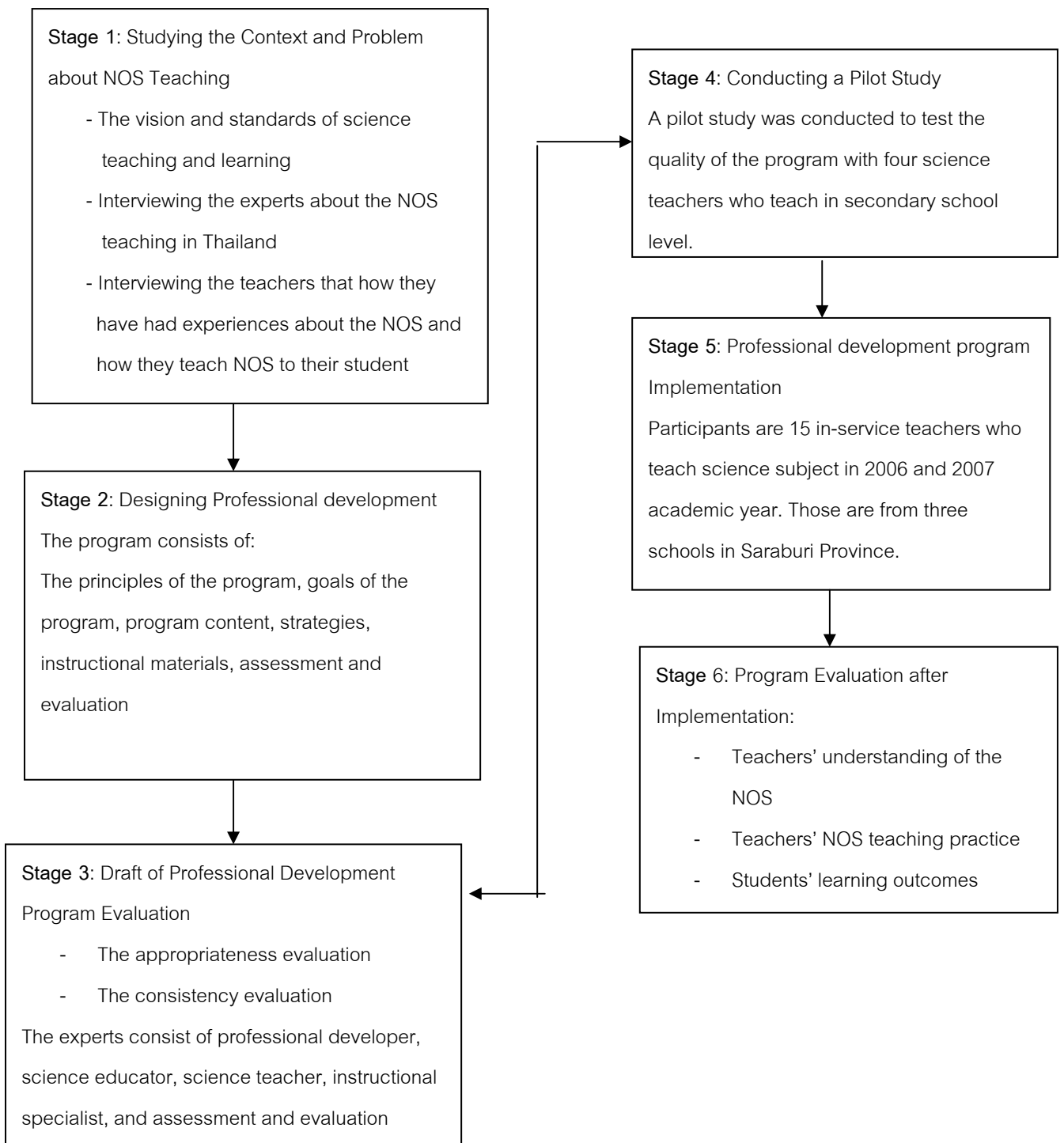


FIGURE 3 THE OVERVIEW OF THE RESEARCH METHODOLOGY

The procedures of each stage are as follows:

Stage 1: Studying the Context and Problem of the Nature of Science Teaching

The purpose is to investigate and study the relevant literature and the real situation including the problem situations in order to bring the findings for designing the professional development program. 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 participating teacher has been investigated for their understanding and teaching of the NOS in the first semester of the 2006 academic year.

This stage is divided into three steps:

Step 1: Studying the vision and standards of science teaching and learning

Step 2: Interviewing the expert about the NOS teaching in Thailand

Step 3: Interviewing the teachers: how they have had experiences in learning and teaching the NOS

The following sections describe the details

Step 1: Studying the vision and standards of science teaching and learning

The researcher studied and reviewed the NOS recommendations in science curricula in Thai and international articles. (e.g., the Basic Education Curriculum A.D. 2001; Science for all American (AAAS). 1993); National Research Council; The National Curriculum for England; & Science in the New Zealand Curriculum). Several research reports about students and teachers' misconceptions about the NOS and the needs of teacher education were also reviewed.

Step 2: Interviewing the experts about the NOS teaching in Thailand

Four experts (two science educators and two science teachers) were interviewed. The questions are about the aspects of the NOS that should be taught to secondary students, how teacher should teach them and how to improve or enhance teachers to integrate the NOS into their teaching.

Step 3: Interviewing the teachers about their NOS learning experiences and observing their teaching practice

Twenty-three in-service science teachers who teach science subjects (general science, chemistry, physics, biology and Earth science, astronomy and space science) were informally interviewed. Five schools were selected from 11 schools in Saraburi Province, Area 1 by simple random sampling (Gall; Gall; & Borg. 2002:171).

Stage 2: Designing the Professional Development Program

This stage is the designing step of the draft professional development program on developing teachers' understanding of the NOS and their classroom practices. This phase is an intermediate phase. Then, the findings from Stage 1 have been considered in the construction of an in-service teacher professional development program for the NOS instruction. This program has also been constructed based on general frameworks derived from existing literature of the NOS instruction.

The design of this professional development program was considered based on this content framework, data gathered from the previous instruments, and Thai science standards documents as well as the affective teacher development model, approaches to teacher development based on the social constructivist perspective, and the explicit approach for the NOS instruction for developing teachers' understanding of instruction of the NOS.

In this stage, the professional development program that is intended to help science teachers acquire the knowledge necessary to successfully and explicitly teach NOS in their science classes was designed.

Program Features

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 affected 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 NOS.

Objectives of the Program

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

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

- Assess and evaluate their understanding of the concepts and instruction of the NOS;
- Discuss and recognize the importance of the NOS in their science teaching.

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

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

- Analyze, discuss and reach conclusions about content strands and intended outcomes, teaching and learning processes, and assessments for the NOS from the manual of content of science learning;

- Study the model lesson plans and learning materials designed based on the explicit instructional approach for the NOS 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;

- Discuss and generate the characteristics of good teaching approaches for the NOS instruction for their classroom context;

- Reflect on the characteristics of good teaching approaches for the NOS instruction for their classroom context and make decisions for further improvement.

2. 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 NOS including hands-on and minds-on activities and inquiry learning processes;
- Lesson plan design, implementation, and evaluation.

3. Assessment of Program

The researcher can assess and evaluate the program from;

1. Observe teachers' participation in discussion, reflection, and presentation while engaging in activities. The teachers 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 NOS,
3. Reflective journals of the teachers which reflect their understanding of concepts and instruction of the NOS gained from participating in the program
4. Pre- and post-test and follow up interview to assess the teachers' understanding of concepts and instruction of the NOS gained from participating in the program

Stage 3: Draft of Professional Development Program Evaluation

The purpose of program evaluation is to assess the effectiveness of the draft program before its implementation. The draft program was evaluated regarding to appropriateness and consistency of the program elements. Five experts who evaluated the draft program consisted of a professional developer, a pedagogical specialist, an

assessment and evaluation specialist, a science educator, and a secondary science teacher.

The result of the program (see Appendix B), appropriateness evaluation showed mean scores range from 4.20 to 5.00 and standard deviation from 0.00 to 0.49 which means the program was appropriate at high level to very high level.

The evaluation of consistency of the draft program from experts' mark indicates that the composition of the draft program was consistently determined. Results of the Item Objective Consistency (IOC) are range from 0.8 to 1.0.

After analyzing the data obtained from the program evaluation form, the draft program was improved according to the experts' suggestions.

Stage 4: Conducting a Pilot Study

The purpose of conducting a pilot study is to test the quality of the draft program before implementing the program and to inspect the feasibility of using the draft program as well as to check wording of handouts and learning materials. In addition, conducting a pilot study helps to reveal the problems that happen during the use of the program.

The research tools used in conducting a pilot study are the professional development program that the researcher developed. Professional development program includes lesson plans as well as the learning materials for teachers.

The researcher contacted the director of schools to ask for permission to collect the data. The pilot study is conducted with four in-service science teachers of one school in Saraburi. This group of teachers is not the same group and not in the same school as participants in main study.

Stage 5: Program Implementation

The professional development program consists of 2 phases:

- 1) Developing Teachers' Understanding of the NOS
- 2) Developing Teachers' Pedagogical Content Knowledge for the NOS instruction.

Stage 5 (implementing training program) and Stage 6 (findings of its effectiveness) were conducted simultaneously.

The purpose of the program implementation was to assess the effectiveness of the program, and also to test the feasibility of using the program. In addition, implementation of the program helped to gain information and insight into improving the program.

Participation/Sample

The program was organized into 2 phases. In Phase 1, there were 15 Grades 7-12 teachers joining in the program. All of these teachers were teachers who taught science subject during the 2006 academic year. The second phase was conducted during the 2nd semester of the 2006 academic year and the 1st semester of the 2007 academic year, and there were six teachers participating in this phase.

In the sampling process of this research, firstly the researcher has set the focus on science teacher who teaches science at secondary school level. Then, the researcher requested the school administrators for approaches the samples. These schools have been chosen based on the willingness of school administrators to allow the research to be carried out in their schools. The researcher selected participants who were teaching science in one or more disciplines, from three secondary schools. These participants have been chosen based on their willingness to participate in the professional development program.

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

1. The nature of science instruction questionnaire

1.1 Five-pointed Likert scale questionnaire

This questionnaire consisted of 22 rating scale statements on the ideas of the NOS to find out participant teachers' understanding of specific aspects of the NOS. These statements about the NOS were applied from various assessment instruments (Aikenhead; & Ryan. 1992; Hammerich. 1998; Nott; & Wellington. 1998; Haidar. 1999; Tairab. 2001).

The questionnaire was handed to each participant teacher for responding within approximately 30 minutes both at the beginning and at the end of Phase 1.

In this research the 5-pointed Likert scale questionnaire was developed after the semi-structured interview as a sole instrument for gathering information about participant teachers' understanding of concepts and instruction of the NOS. 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 NOS 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, this questionnaire was constructed to cover different but related and more specific aspects of the NOS. This questionnaire was also designed for gaining supplementary information about teachers' understanding of instructional approaches for the NOS.

1.2 Open-ended questionnaire

In order to investigate teacher's conceptions of the NOS, 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 tried out on three secondary school teachers. In the first phase of this research, each participant teacher was interviewed and was audiotape recorded for approximately 45 minutes.

After the program, participant's understanding of the nature of science was assessed again by the NOS 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.

Then, the information generated from these various sources and techniques was analyzed, categorized and cross-checked.

2. Semi-structured interviews with audiotape recording

In order to investigate teacher's conceptions of the NOS, 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. Then, the semi-structured interview was modified and was tried out on six secondary school teachers. In the first phase of this research, each participant teacher was interviewed and audiotape recorded for approximately 45 minutes.

The semi-structured interview is in between two extreme types of 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). 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.

3. Observations with field notes and informal interviews

The non-participant observation technique was used in this research (Verma. 1998). In the second 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 the real classroom setting.

During the second phase of the research, the researcher had spent some time visiting their schools and had informal interviews with them after doing classroom observation. The researcher visited each participant's science class for 1-2 periods. The interview aimed to obtain information about the teaching objectives, intentions, and perceptions of that classroom teaching.

4. Document and content analysis

This research refers to the technique following Anderson's (1994, cited in Verma. 1998: 112) 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 NOS, various documents were gathered in the first and the second phase of the study. These documents were participants' lesson plans, teachers' notes, and written documents generated during participation in the program. Finally, the findings were interpreted and triangulated with data from other sources.

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. Participant's self evaluation also had been gathered in reflective writing.

Stage 6: Program Evaluation after Implementation

This phase was designed to investigate the effectiveness of the program on teacher's understanding and teaching of the NOS to answer the research questions as stated in Chapter 1. Before, during and after the implementation of program, each participant was investigated to identify the development of their understanding and teaching of the NOS in order to determine the effectiveness of program.

The effectiveness of the program was determined in the form of teachers' development of their understanding of the NOS and their teaching practices. The effectiveness of the program is judged according to the following criteria:

- 1) Teachers' understandings of NOS after attending the professional development program are better than before attending.
- 2) Teachers improve their NOS teaching in that they change their practice to a more explicit NOS instruction.
- 3) Students understand some aspects of NOS that their teacher mentioned in each lesson.

CHAPTER 4

FINDINGS

This chapter presents the findings from the *Stage 5: Professional development Program Implementation* and *Stage 6: Program Evaluation after Implementing*. The findings were gathered and organized to answer each research question being shown below:

- (1) What are in-service teachers' views of the NOS?
- (2) How do in-service teachers change (if any) their views about the NOS derived from the training program?
- (3) How do teachers generally address the NOS in their teaching?
- (4) Do teachers improve their pedagogical knowledge related to NOS through their three teaching sessions?
- (5) What are the possible sources or specific supports from the professional development program for improving their practice of teaching the NOS?

At the end of Chapter 4, the impact of teachers' practices on students' learning outcomes was reported as the overall impact of the training program. The researcher gathered related documents which students generated during their learning in science classes.

1. Results of the Teachers' Understanding of the Nature of Science

To answer the research question 1 and 2, the 5-point Likert scale questionnaire and the open-ended questionnaire followed by semi-structured interview were employed to the participant teachers.

The results are presented in two sections. First, the NOS views identified as a result of the 5-point Likert scale questionnaire are presented. Second, the outcomes in NOS view that resulted from the open-ended questionnaire and semi-structured interview are reported.

1.1 Teachers' responses to the 5-point Likert scale questionnaire

The purpose of using this questionnaire is to engage teachers' minds on thinking of the question "what is science all about?"

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 NOS concepts.

The positive statements to traditional view are in items; 1, 2, 5, 6, 11, 15, 17, 21 and 22

The positive statements to contemporary view are in items; 3, 4, 7, 8, 9, 10, 12, 13, 14, 16, 18, 19 and 20

Fifteen teachers' responses to 22 rating scale items of the NOS statements before and after attending the program are shown in Table 3 below (see also Appendix C).

The sign ☒ and ☓ refer to the position of teachers' agreement on the rating scale before and after attending the training program, respectively. It also refers to their point of view on each statement in the range of traditional to contemporary view, contemporary to traditional view or in the range of misconception to right conceptions.

TABLE 3 TEACHERS' RESPONSES TO THE NATURE OF SCIENCE STATEMENTS
BEFORE AND AFTER ATTENDING THE PROGRAM

Statements	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Mean	SD
1 Scientists have no idea of the outcome of an experiment before they do it.	Traditional Contemporary					1.73	0.44
	<i>before</i> ⊗						
	<i>after</i> ⊗					1.13	0.34
2 All scientific ideas are discovered and tested by controlled experiments.	Traditional Contemporary					1.87	0.62
	<i>before</i> ⊗						
	<i>after</i> ⊗					1.20	0.40
5 Imagination and creativity are not be used in coming up with hypotheses and theories.	Traditional Contemporary					1.93	0.68
	<i>before</i> ⊗						
	<i>after</i> ⊗					1.20	0.40
6 Scientific method is the power tool that scientists have to follow its steps for the true knowledge.	Traditional Contemporary					1.73	0.77
	<i>before</i> ⊗						
	<i>after</i> ⊗					1.33	0.47
11 When social scientific issues occurred, only scientists or group of professionals take part to make decision.	Traditional Contemporary					1.80	0.65
	<i>before</i> ⊗						
	<i>after</i> ⊗					1.73	0.44
15 The best way to prepare to become a scientist is to master the scientific body of knowledge available in the finest texts.	Traditional Contemporary					1.40	0.49
	<i>before</i> ⊗						
	<i>after</i> ⊗					1.33	0.47
17 Scientists are not influenced by personal expectation/beliefs and prior knowledge. When scientists make arguments, their personal bias does not have an influence.	Traditional Contemporary					2.00	0.73
	<i>before</i> ⊗						
	<i>after</i> ⊗					1.73	0.44
21 Science can completely explain the world and how it works.	Traditional Contemporary					2.07	0.93
	<i>before</i> ⊗						
	<i>after</i> ⊗					1.67	0.47

TABLE 3 (continued)

Statements	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Mean	SD
22 Scientific theories describe a real external world which is independent of human perception.	Traditional Contemporary					1.53	0.88
	<i>before</i>						
	<input checked="" type="checkbox"/>					1.07	0.25
	<i>after</i>						
3 The social system imposes some restrictions on openness in technology.	Contemporary Traditional					4.67	0.47
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.93	0.25
	<i>after</i>						
4 Everyone can exercise them in thinking scientifically about many matters of interest in everyday life.	Contemporary Traditional					4.47	0.50
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.60	0.49
	<i>after</i>						
7 For most major ideas in science, there is much experimental and observation confirmation and therefore unlikely to change greatly in the future.	Contemporary Traditional					3.93	0.93
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.67	0.47
	<i>after</i>						
8 There are many matters that cannot usefully be examined in a scientific way.	Contemporary Traditional					4.67	0.47
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.67	0.47
	<i>after</i>						
9 Because of reliance on evidence, science value is placed on the development of better instruments and techniques of observation, and findings of any one investigation or group are usually checked by others.	Contemporary Traditional					4.40	0.49
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.53	0.50
	<i>after</i>						
10 Scientific research is economically and politically determined.	Contemporary Traditional					4.47	0.88
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.67	0.47
	<i>after</i>						
12 Scientists assume that there is no way to secure complete and absolute truth. Increasingly accurate approximations can be made to account for the world and how it works.	Contemporary Traditional					4.13	0.81
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.33	0.47
	<i>after</i>						

TABLE 3 (continued)

Statements	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Mean	SD
13 Some scientists work in teams, and some work alone, but they need to communicate their scientific results and require peer review.	Contemporary Traditional					4.07	0.25
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.13	0.34
	<i>after</i>						
	<input type="checkbox"/>						
14 Scientific concepts do not emerge automatically from data, but scientists make inference from that data.	Contemporary Traditional					4.67	0.47
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.67	0.47
	<i>after</i>						
	<input type="checkbox"/>						
16 It is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered.	Contemporary Traditional					3.87	0.89
	<i>before</i>						
	<input type="checkbox"/>					4.27	0.44
	<i>after</i>						
	<input checked="" type="checkbox"/>						
18 Science assumes that the universe is a single system in which the basic rules are everywhere the same. Knowledge gained from studying one part of the universe is applicable to the other parts.	Contemporary Traditional					4.13	0.34
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.13	0.34
	<i>after</i>						
	<input type="checkbox"/>						
19 Science is a process for producing knowledge. Science education should be more about the learning of scientific processes than the teaching of scientific facts.	Contemporary Traditional					4.60	0.49
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.73	0.44
	<i>after</i>						
	<input type="checkbox"/>						
20 Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanation.	Contemporary Traditional					4.53	0.50
	<i>before</i>						
	<input checked="" type="checkbox"/>					4.47	0.50
	<i>after</i>						
	<input type="checkbox"/>						

Table: Adapted from Tepkanya Promkatkeaw (2007)

From the statistical analysis of the whole rating scale part of 5-point Likert scale questionnaire, fifteen participating teachers' mean score of all question items before and after attending the training program is summarized and shown in Table 4 below.

TABLE 4 TEACHERS' MEAN SCORE OF ALL QUESTION ITEMS BEFORE AND AFTER ATTENDING THE PROGRAM

Views of Science	Mean Score ($n=15$)	
	Before the Program	After the Program
Traditional Views	1.78	1.38
Contemporary Views	4.35	4.52

Table 4 shows that teachers tended to be more supportive of the contemporary views after completing Phase 1 of the training program (when compared to their views in the beginning of the training program). On the other hand, teachers tended to show less agreement with traditional views when finishing training program.

1.2 Teachers' Responses to the Open-Ended Questionnaire

This questionnaire is an open-ended form (see Appendix D). Fifteen teachers responded to this questionnaire at beginning and after Phase 1. The findings were organized into two sections: 1.2.1 Changes in the NOS Views; and 1.2.2 Establishing Connections among the NOS Aspects.

1.2.1 Changes in the NOS Views

In their pretest responses and interviews, all articulated, to some degree, the meaning of most of the aspects. Five out of eight aspects of the NOS those teachers initially held were misconceptions: tentativeness; creativity and imagination; theory-laden; observation and inference; and subjectivity. At the end of Phase 1, all teachers seem to improve their views about the NOS.

At the completion of Phase 1, all participants demonstrated abilities to articulate detailed descriptions of all targeted aspects of the NOS. Although, the level of

detail still ranged from simple affirmation that the aspect applies to science to very elaborative descriptions indicative of deeper understandings. The researcher looked for evidence of change resulted in two main change categories that differ in degree of change. A change was considered (1) “major” if there was evidence of an overt switch from a misconception/ naïve view initially to a view that is in more agreement with that prompted in the program, or (2) “enhancement” if a teacher demonstrated improved understandings over his/her initial profile, thus indicating a shift in the desired direction. Table 5 (see pages 74-75) summarizes changes. For each teacher, the NOS test responses and corresponding interview transcript will be reviewed, and a summary profile generated to represent that teachers conceptions. Each aspect will be scored with a “+” to indicate the teacher’s agreement on particular aspect. Score of a “++” indicates the teacher’s abilities to articulate the meaning of the aspect in his/her own words through supporting examples from professional development program, or a “+++” to indicate the teacher’s abilities to articulate the meaning of the aspect in his/her own words and provide examples different from those presented in professional development program. Additionally, data were examined for reference to connections among aspects. Post program NOS profiles were generated via the same process, utilizing the NOS posttest questionnaires and follow-up interviews. A couple paragraphs below are the explanations and examples of teachers’ responses to the open-ended questionnaire and interviews.

Observation/Inference: A majority of teachers indicated that atomic structure is a “model constructed through experimentation and inference. However, two of participant teachers held naïve views about observation and inference. They thought “proof” in science indicated a “seeing is knowing” view. In response to the fourth item of the open-ended questionnaire followed by interview, one teacher stated, “Scientists now know about atom because they saw them through special electron microscopes“ (T4_{pre}). When teachers were asked to describe how scientists determined the structure of the atom before they had an electron microscope, no teacher talked about finding evidence to support the model of the atom, just that scientists use “facts”. Another teacher that held naïve view of observation and inference told that “In the past we didn’t sure about atom structure because we can’t see

it...(T5_{pre})” That could mean this teacher believed that indirect evidence was not sufficient in determining the atom.

At the end of the program all teachers had appropriate understandings of observation versus inference. And Teacher 4 changed her view as shown below.

In the past, scientists constructed the model of an atom by testing, observing, and imagination its behavior or properties based on charge properties and relationships with other atoms and molecules. Scientists are fairly certain about the structure. But it is only a theory because scientists scientists had never seen an atom, particles and its orbitals. (T4_{post})

1.2.2 Establishing Connections among NOS Aspects.

Other enhancements involved establishing connections among aspects of the NOS and then to science in a broader sense. For example, Teacher 1 demonstrated enhanced view and showed the connection of the aspects of empirical basis with interrelation of science and technology. Teacher stated that “scientists use evidence to explain the world... some ideas of a scientist was not accepted by other because there is not enough evidence or data to support them. If technology about that area was more advanced, scientist could have data to support their ideas and other scientists can confirm. That idea/or theory would be accepted because of new technology leading to evidence” (T1_{post}).

Data from teachers’ responses change to the open-ended questionnaire was shown in Table 5.

TABLE 5 CHANGE IN VIEWS OF NOS ASPECTS RESULTS FROM OPEN-ENDED QUESTIONNAIRE

Participants	Empirical	Tentative	Creative and Imagination	Theory-laden	Social and Cultural	Observation and Inference	Subjective	Science and Technology
Teacher 1	E,C(++)	E(++)	E(++)	E(++)	E(++)	E(+++)	E(+)	E,C(++)
Teacher 2	E(++)	E(++)	E,C(+)	E(++)	E(++)	E,C(++)	E,C(+)	E(++)
Teacher 3	E(+)	E,C(+)	E(+)	E(+)	E,C(++)	E,C(++)	E(+)	E,C(++)
Teacher 4	E(++)	E(++)	M(+)	E	E(++)	M(++)	E(+)	E(++)
Teacher 5	E,C(++)	E(++)	E(++)	E,C(+)	E(+)	M(++)	E(+)	E(++)
Teacher 6	E(+)	E(+++)	E(+)	M(+)	E(++)	E(+)	E(+)	E
Teacher 7	E(+++)	E(+++)	E(+)	E(++)	E(+++)	E(++)	E(++)	E(+++)
Teacher 8	E(++)	E,C(++)	E,C(+)	E(++)	E(+++)	E,C(+++)	E,C(+)	E(+++)
Teacher 9	E,C(++)	E(++)	E(++)	E(+)	E,C(++)	E,C(++)	M	E,C(++)
Teacher 10	E(++)	M(++)	E(+)	E(+)	E(+++)	E(+++)	M(+)	E(+)

Continued

Note: M: major change from misconception to informed view; E: Enhanced (started out adequate, but gained); C: showed connections among aspects. Final NOS views: + provides a definition or affirmative response; ++ provides a description in own words, examples from program; +++ provides a description in own words and additional supporting examples.

TABLE 5 (Continued)

Participants	Empirical	Tentative	Creative and Imagination	Theory-laden	Social and Cultural	Observation vs. Inference	Subjective	Science and Technology
Teacher 11	E,C(+++)	E,C(++)	E(+)	E(++)	E(++)	E,C(+++)	E,C	E(++)
Teacher 12	E(+)	E(++)	E	E(++)	E(++)	E(++)	E(+)	E(++)
Teacher 13	E(+)	E(+)	E(++)	M	E(++)	E(++)	M	E(++)
Teacher 14	E(++)	E,C	E(++)	E,C(+)	E(++)	E(++)	E,C(+)	E(++)
Teacher 15	E(++)	E(++)	M(+)	E(+)	E(+)	E(++)	E(++)	E(++)

Note: M: major change from misconception to informed view; E: Enhanced (started out adequate, but gained); C: showed connections among aspects. Final NOS views: + provides a definition or affirmative response; ++ provides a description in own words, examples from program; +++ provides a description in own words and additional supporting examples.

2. Results of the Teachers' Teaching of the Nature of Science

To answer the third and the fourth research questions, teachers' lesson plans, field note, transcript of lessons and reflective writings were collected.

As an attempt to trace the changes in teaching NOS, six science teachers were assigned three teaching sessions for integrating or addressing some aspects of NOS in their teachings at the beginning, during and the end of Phase 2 of training program. The first teaching session was conducted at the end of the first phase of the professional development program that focuses on developing teachers' understanding of the NOS. The second teaching session was scheduled during the second phase. The third teaching session was conducted at the end of the second phase. These will help identify the effectiveness of an in-service professional development program on the instruction of the NOS.

A total of 17 lessons were presented through three teaching sessions. The researcher sorted all lessons into three Levels: implicit, didactic and explicit approach. The results of Phase 2 were reported in two sections: (2.1) General Ways of Integrating NOS in Each Level; 2.2) Changes in NOS instruction during the training program

2.1 General Ways of Integrating NOS in Each Level

In the following section, each teacher group is identified by a letter and a number. The letters "T" for Teacher and "G" for Grade Level are used to identify lessons in each teaching session. The numbers, which run from 1 to 6 in "T" and from 7 to 12 in "G", identify each lesson in each teaching session. For example, T2G12 represents the teacher number 2 teaching his/her Grade 12 students.

Level 1: Implicit Teaching by Only Doing NOS

From the analysis of 4 Level 1 lessons, the teachers initially appeared to believe that students would learn the NOS by doing science. Pieces of evidence for implicit teaching were detected in lesson plans as well as in their teaching. All lesson plans for those Level 1 lessons included target aspects of the NOS, but most of them did not incorporate how to address the target aspects of the NOS. Indeed, aspects of the NOS were lightly specified as outcome in their instructional objectives (Bell; Lederman; & Abd-El-Khalick. 2000). The objectives were related to doing science and/or only science content.

One middle grade (T1G7, Physics) example is as follows: this activity is about springs and forces. Objective of this activity is to investigate the relationship between the change in length of a spring and the force applied to it.

Inquiry and Nature of Science:

- Plan and conduct a simple investigation
- Creativity
- Observation and Inference

It seems that the teachers chose certain aspects of the NOS based on what their students would do in their lessons. As an example, the target aspect of the NOS and its short description from one lesson plan indicates that certain aspects of the NOS were thought of as what students would do.

Creativity: students have to be creative to design the data table and draw a graph presenting their finding

Observation and Inference: students use observation skill and make an inference conclusion from the data

Scientific inquiry: student reports the objective, hypothesis, method, a collection of data, an analysis of data and draws a conclusion

(T1G7, Physics)

One chemistry class (T2G10, Chemistry) used balloons to explore the structure of covalent molecule. Two target aspects of the NOS were written down on the lesson plan.

- Observations and inferences
- Creativity and imagination

In this class lesson plan, students were supposed to make observations, develop an explanation of the structure of covalent molecule using balloons. No plan for teaching the target aspects of the NOS was found. The teachers appeared to assume that students would learn those two aspects of the NOS above through observing, developing an explanation and presentation. This teaching was consistent with its lesson plan. Students inflated balloons and tied two balloons together. Teacher asked students to draw the shape

of molecules that they got from their balloons. By altering the number of balloons, students learnt to make predictions about molecular structure.

(T2G10, Chemistry)

The careful analyses of Level 1 lessons indicated that the teachers' implicit teaching was not ascribed to the confusion between science processes and aspects of NOS as suggested by Abd-El-Khalick et al. (1998). Rather, on thinking about how to teach NOS, the teachers intuitively treated the NOS as doing things.

Level 2: Didactic Teaching

A total of 7 lessons at Level 2 were found. Unlike Level 1 lessons that did not show any attempts to teach the NOS, the teachers in Level 2 took time for addressing the NOS. The way of integrating the NOS in their lessons was to assign the NOS discussion after students' activities were done. However, this discussion looked separated from the activities that students had been engaged in. Through the activities students were taught science content. After teaching target science content, teachers didactically wrapped up the NOS discussion without a reflective conversation on students' activities. The activities that students had done appeared to be only for teaching science content. All the Level 2 lessons were identified as concentrating on teaching science content and making a simple didactic explanation of certain aspects of the NOS.

For example, one secondary class (T4G11, physics) provided students with demonstrations regarding wave reflection and refraction. Students were asked to observe the demonstration about wave phenomena conducted by the teacher and to define what wave reflection and refraction were. Students explained what happened based on their own definitions. The teacher then revised some definitions about wave reflection and refraction that were inappropriate to explain the demonstration. Teacher came to the final definition of law of reflection that "the angle of incidence equals the angle of reflection"

After that, the teacher initiated a discussion on the NOS. But, it turned out a short comment rather than a discussion:

“you (students) could make an observation from demonstrations and from those observations you were able to make an inference from your prior knowledge and you knew that the refraction occurs when the wave encountering a boundary between different mediums changes its speed and wave length and as a group, like scientists do, you were discussing things you knew and things you were learning as you came up with those explanation of wave phenomena”

(T4G11, physics)

The teachers did not give students the opportunities to reflect on the NOS. As shown in the final comment above, students inferred what happened. The teacher could ask students what they inferred and why they had different inferences and could stress that the concepts of wave reflection and refraction are inferential entities. Rather, they appeared to focus on teaching the concepts, mathematical calculation and index of refraction.

In one middle school level (T6G9, Biology), as another example, one class was taught the water transportation in plant. In this lesson, teacher prepared slides (thin cross section of plant) for students to observe through microscope to discover the location of xylem cells which were stained blue color. At the beginning of the lesson, a teacher mentioned using observations and inferences in studying water transport in plant.

T (Teacher 6): We will make some observations, and then inferences for why it happened.”

...

S (Student): There are blue dots on the bottoms.

T: What are your inferences for what happened?

S: It absorbs blue water.

S: There are tubes in a tree and tree absorbs water.

T: So we are inferring that the tree absorbs the water by our observations that the blue water is now inside the plant.

...

But, that was all. No further attempt to reflect aspects of difference between observations and inferences that student had learned was identified during the rest of the

lesson. Only structure, function of water transport and the direction of transporting water in plant was discussed and addressed.

(T6G9, Biology)

Level 3: Explicit and Reflective Way of Making a Connection with Students' Doing NOS

Six lessons out of 17 were graded as Level 3. General features of lessons at this Level are to have students exposed to reflective discussions on the NOS and to assess students' understanding of the NOS. In teaching certain aspects of the NOS in an explicit and reflective way, two different strategies were identified; an inductive NOS discussion and the NOS teaching in the whole activity.

An inductive NOS discussion: Five lessons at Level 3 comprised NOS discussion at the end of their lessons as Level 2. Unlike Level 2, however, the teachers in Level 3 lessons led a reflective conversation with students to help them understand certain aspects of the NOS by making a connection between students' activities in the lessons and the NOS.

One physics class (T3G10, Physics) targeted the magnetic field. In this lesson, students were asked to draw picture of the directions of magnetic field lines around one and two magnetic bars (iron filings are scattered around magnetic bars). Students were given materials: two magnetic bars, iron filings and a magnetic compass for each group. A teacher gathered students' drawing results about which students made their explanations and helped students understand the magnetic field. Then, she also addressed the difference between observation and inference aspect of the NOS while reviewing students' results. Teacher tried to help students reflect on what they did in this lesson for integrating the observation versus inference aspect of the NOS. The part of the NOS discussion is shown below.

T (teacher 3): What do you infer by seeing iron filings around the magnetic bars?
What's your inference?

S(student): There is a magnetic field.

T: Can you actually see the magnetic field? Are you observing the magnetic field?

S: No.

T: You are inferring the magnetic field is there. You cannot see magnetism, but you can feel its effects.

(T3G10, Physics)

This class made a reflective conversation for addressing the observation versus inference aspect of the NOS in the context of teaching the magnetic field. A teacher made a NOS discussion after the activity was done. The questions that she used to help students understand the observation versus inference aspect of NOS included “What did you make? Did you make an observation or did you make an inference?” “How did you infer that?” “Do you think scientists make inferences as they attempt to derive an answer to question about natural phenomena?” “Do you think scientists do the same thing that you have done today?” “Can you give me an example?” “Did we see all groups made the same inferences about the experiment?” “Does anyone come up with any different observations?”

NOS teaching in the whole activity: In this lesson, the teacher specified target aspects of the NOS in the introduction of the lesson and attempts to address the target aspects were identified not only in the discussion at the end of the lesson, but also while students participated in an activity (debate and role play) and their group presentation. For example, one class (T5G12, Biology) planned the lesson for teaching safety of DNA technology and aspects of society and morality for 12th graders.

(T5G12, Biology)

2.2 Changes in the Frequency of Level

In the first teaching session more than half of the classes (4 out of 6) demonstrated a Level 1 lesson in which students were exposed to hands-on activities, but taught science content only, not the target aspects of the NOS. Consistent with prior research (Abd-El-Khalick; et al. 1998), the teachers did not much consider the NOS when planning for teaching. Lesson plans heavily focused on teaching science content through hands-on activities. A total of 2 groups presented Level 2 lesson. The change in the frequency of Level is shown in Table 6.

TABLE 6 THE FREQUENCY OF EACH LEVEL IN EACH TEACHING SESSION

Teaching session	1 st			2 nd			3 rd		
Level	L1	L2	L3	L1	L2	L3	L1	L2	L3
Teacher 1	✓				✓				✓
Teacher 2	✓			-	-	-*			✓
Teacher 3	✓				✓				✓
Teacher 4		✓				✓			✓
Teacher 5	✓				✓				✓
Teacher 6		✓			✓			✓	
Total	4	2	0	0	4	1	0	1	5

* Teacher 2 was absent while conducting the 2nd teaching lesson.

In the second teaching session, the number of Level 1 lesson decreased from 4 to none. After two teaching sessions, it seems that three more groups moved from Level 1 to Level 2. In the teacher 6 (T6), there was no change in the number of Level 2 lesson, but other teachers presented desirable lesson-graded as Level 3 or Level 2

At the end of the training program the third teaching session was performed. All six teachers tried at least to illustrate certain aspects of the NOS. No Level 1 lessons were found in this teaching session. It was desirable that the number of Level 2 decreased from four to one and Level 3 increased. Five lessons in Level 3 were presented; therefore, teachers demonstrated more explicit and reflective approaches. Indeed, in all lessons of Level 3, assessment pieces were assigned for checking students' understandings of target aspects of the NOS. The teachers provided students with questions, had them taken a quiz, and gave homework including assessment questions or assigned some activities.

The result indicated that the teachers improved their pedagogical knowledge related to teaching the NOS from an implicit to an explicit and reflective approach. However, implementing explicit and reflective instruction for the NOS is not simple. More teachers' work on effective approaches to explicit and reflective instruction is required.

3. Results from Teachers' Self-Reflection on Their Improvement on the Nature of Science Instruction

To answer the fifth research question that “what were the possible sources or specific supports from the professional development program for improving their practice to teaching the NOS?” The teachers in the study were asked to reflect their possible sources or specific supports for improving their teaching of the NOS. Teachers were asked to respond to the survey that is the five-point Likert scale about the possible sources or specific support of their improving their teaching (such as: certain parts of course content, or activities or others).

TABLE 7 POSSIBLE SOURCES FOR IMPROVING THEIR TEACHING OF THE NATURE OF SCIENCE

Source of change	Means ($n=6$)	SD
Philosophy of Science	3.87	0.89
Science Stories	4.93	0.25
Inquiry of Science	3.93	0.93
Model Lesson	4.47	0.50
Teaching session	4.07	0.25
Reflective Writing	4.13	0.34
Mentoring and coaching	3.87	0.89

The results from Table 7 could be inferred that many teachers attributed their view changes in the instruction to science story activities, teaching session and model lesson. The science story activities, such as “Understanding Our Universe” (see Appendix A), were placed on Phase 1. During the workshops in Phase 2, three teaching sessions were assigned to the teachers as the researcher looked for the evidence of their improvement. This activity was also helpful for teachers practicing their new knowledge and new approach

to teach science. After their teaching, the researcher and peers gave some feedbacks or suggestions for better teaching of the NOS next time. The reflective writing was used as a tool for teachers' self evaluation of their practice in Phase 2. However, not many teachers perceived their view changes as deriving from direct instruction about philosophy of science, inquiry of science and mentoring and coaching strategies. They suggested that the researcher should extend the period of practice teaching of the NOS, and visit their classes more often and conduct a model teaching in their class.

4. Results from the Study of the Students' Learning Outcomes

As mentioned earlier, in Phase 2 of the professional development program, six teachers freely chose the classes and contents that they wanted to teach in this implementation phase. Teachers made decision for choosing any aspects of the NOS that were appropriate for integration with science content in each science class. Students would learn a few aspects of the NOS in each class; therefore, the questionnaire or tests were not appropriate to those students. And the researcher did not want to pressure participant teachers by directly test their students. However, to demonstrate the overall impact of professional development, the student learning outcomes were also traced. The ways for gaining the information were the examination of teacher-student conversations, students' works, making informal interviewing students and observing them learning in science classrooms.

The researcher could tracked the students' understanding of the NOS in the following aspects that were shown in Table 8.

TABLE 8 STUDENTS' UNDERSTANDING OF SOME ASPECTS OF THE NATURE
OF SCIENCE

Aspects of the nature of science	Sources of data
1 Empirical basis	<ul style="list-style-type: none"> - Teacher - Student Conversation - Concept map
2 Tentativeness	<ul style="list-style-type: none"> - Board Presentation - Teacher - Student Conversation - Booklet
3 Creativity and Imagination	<ul style="list-style-type: none"> - Concept map - Teacher - Students Conversation
4 Theory-laden	<ul style="list-style-type: none"> - Teacher - Students Conversation
5 Sociocultural	<ul style="list-style-type: none"> - Board presentation - Role play activity - Debate activity - Teacher - Students Conversation
6 Observation and inference	<ul style="list-style-type: none"> - Concept map - Group Presentation - Test items - Teacher - Students Conversation - Report

TABLE 8 (continued)

Aspects of the nature of science	Sources of data
7 Science and Technology	<ul style="list-style-type: none"> - Teacher - Students Conversation - Debate activity - Report - Broad presentation
8 Subjectivity	<ul style="list-style-type: none"> - Brochure - Teacher - Students Conversation

Table 8 showed eight aspects of the NOS that the researcher could track the students' understanding of the NOS from 17 teaching lessons. These understanding data came from transcript of the conversation between the teacher and students; students' works and their activities (e.g., role play activity, presentation, brochures). The most frequent aspect of science that was introduced to the students is observation and inference. The teachers always use questioning strategies to stimulate their students to think about the aspect of the NOS that teachers intended to integrate in the classroom. In two classes the teachers use the test items about the observation and inference to assess the students' understanding of the distinction between the observation and inference. Teachers always assigned their students to do some pieces of work after finishing the lessons (homework) for the purpose of evaluating and following-up the students' understanding of the nature of science.

Chapter 5

Conclusion and Discussion

This chapter presents the conclusion of the study, discussion of research findings, and recommendation.

The research questions

The research questions guiding the investigation are:

- (1) How do in-service teachers understanding concepts of the NOS?
- (2) How do in-service teachers change (if any) their views about the NOS derived from the training program?
- (3) How do teachers generally address the NOS in their teaching?
- (4) Do teachers improve their pedagogical knowledge related to the NOS through their lessons?
- (5) What are the possible sources or specific supports from the professional development program for improving their practice in teaching NOS?

Research Objectives

The main purpose of this study is to develop in-service secondary school teachers' understanding of the nature of science in both conceptions and instruction. The second aim is to propose and develop an effective program for in-service secondary school teachers' professional development on the instruction of the nature of science.

Research Hypotheses

1. Teachers' understanding of the NOS after attending the professional development program is in more agreement with contemporary views than that before attending the program.
2. Teachers' understanding of the NOS after attending the professional development program shows improvement to adequate level than that before attending the professional development program.

3. Teachers' practice shows the improvement (shift from the implicit or didactic approach to explicit and reflective approach) in teaching the NOS through three teaching sessions.

Participants/Sample

Phase 1: Developing teachers' understanding of NOS

The participants are 15 science teachers who taught science subjects to secondary students. They are from three schools in Saraburi. Those schools are selected by convenience sampling. Fifteen science teachers in these schools are selected by volunteer sampling.

Phase 2: Developing teachers' practice for NOS instruction

Six science teachers who had been participated in phase 1 of the training program continued to participate in Phase 2. They were assigned to teach the NOS in their real classroom setting.

The research methodology

Stage 1: Studying the Context of Problem of the NOS

Stage 2: Designing Professional Development

Stage 3: Draft of Professional Development Program Evaluation

Stage 4: Conducting a Pilot Study

Stage 5: Program Implementation

The PD program consists of 2 sessions:

- 1) Developing Teachers' Understanding of the NOS
- 2) Developing Teachers' Pedagogical Content Knowledge for the NOS instruction.

Stage 6: Program Evaluation after Implementation

This phase was designed to investigate the effectiveness of the program on teacher's understanding and teaching of the NOS to answer the research questions. Before, during and after the implementation of program, each participant has been investigated to

identify the development of their understanding and teaching of the NOS in order to determine the effectiveness of program.

The professional development program was evaluated regarding of:

- Teachers' understanding of the NOS
- Teachers' practice related to the NOS

Impacts of teachers' practices on students' learning outcomes were also studied.

Conclusion

To evaluate the effectiveness of the professional development program, the teachers' understanding of the NOS and teaching approach were studied. The findings of this study are summarized as follows:

Phase 1: The results of developing the teachers' understanding of the nature of science

The data were gathered through two questionnaires: 1) 5-point Likert scale questionnaire, 2) open-ended questionnaire.

1) Results from 5-point Likert scale questionnaire

According to the theoretical framework, teachers are required to have contemporary view rather than traditional view of science. The results from the study of the development of teachers' understanding of the NOS indicated that teachers tended to support the contemporary views after completing the phase 1 of the training program compared to their views at the beginning of the training program. On the other hand, teachers tended to show less agreement with traditional views after finishing training program.

2) Results from open-ended questionnaire

The results from study of teachers' understanding of the NOS indicated that after attending the training program, they held more informed views of the NOS than before attending the program. Most of the change was considered as "enhancement" of teacher demonstrating improvement on understandings over his/her initial profile, thus indicating a shift in the desired direction. Some change was considered as "major" that there was evidence of an overt switch from a misconception/naïve view initially to a view that is in more

agreement with that prompted in the program. In the final views, most teachers can articulate the meaning of the aspect in his/her own words through supporting examples from professional development program. Some teacher can articulate the meaning of the aspect in his/her own words and provide examples different from those presented in professional development program. Other enhancements involved establishing connections among aspects of the NOS and then to science in a broader sense.

Phase 2: The results of developing the teachers' pedagogical content knowledge of the nature of science instruction

According to the theoretical framework, teachers are required to model behaviors, strategies, and language that reflect appropriate understandings of the NOS to their students; address explicit/ reflective views of the NOS portrayed in science activities; and set curriculum materials which adequately portrayed the NOS. In the attempt to trace the changes in teaching NOS, six science teachers were assigned three teaching sessions to integrate or address some aspects of the NOS in their teachings at the beginning, during and at the end of Phase 2 of the training program. A total of 17 lessons were presented through the three teaching sessions. The researcher sorted all lessons into three Levels: implicit, didactic and explicit approach. From this result, the teachers were shown to have improved their pedagogical knowledge related to shift the teaching the NOS from an implicit to didactic and to explicit/reflective approach.

Discussion

The results from this study provide insight into teachers' conceptions of the NOS and those strategies which were effective in enhancing teachers improve their understanding and teaching of NOS. The results indicated that the teachers improved their NOS instruction through three teaching practices. Through interventions it has proven possible for secondary teachers to develop informed conceptions of the NOS through an explicit reflective approach (Akerson; Abd-El-Khalick; & Lederman. 2000; Akerson; & Abd-El-Khalick. 2003). Participated teachers became proficient at connecting what students did in their lessons to what scientists do and illustrating a certain aspect of the NOS. In connecting NOS to *doing NOS*, the difference between observations and inferences was the most

frequent aspect of NOS that the teachers addressed. Ten out of 17 lessons were included in this aspect. The teachers may have felt comfortable to incorporate this aspect of the NOS within their lessons because making observations and inferences were the common features of any investigation (Kim; et al. 2005).

The findings of this study indicated that the importance of model lessons where teachers were invited to view lessons enabled teachers to better implement the new strategies in their own teaching were importance. Current work with in-service teachers shows that sustained support that allows teachers to view model lessons that emphasize NOS aspects in their classroom triggers them to develop and teach appropriate NOS conceptions to their own students (Akerson; & Abd-El-Khalick. 2003).

Knowing NOS-pedagogical knowledge (e.g., the difference between an implicit and an explicit approach) does not seem to adequately entail the changes from didactic to reflective NOS instruction (Kim; et al. 2005). Participated teachers in the present study need pedagogical content knowledge (PCK) for NOS instruction that includes sufficient knowledge of the NOS, certain science content knowledge (e.g., its evidence and history of its development), general pedagogical knowledge of generating a student-centered discussion, and NOS-specific pedagogical knowledge of making connections between that student do and what scientists do and between the NOS and the conceptual structure of science content.

Recognition of the difference between doing and knowing things appears to affect the teachers' instruction of NOS in this study too. As described in Level 1 lessons, the teachers' initial belief about teaching the NOS was associated with having students in a situation of *doing NOS*. Situations in which students brought up different interpretations, changed their own explanations, created a model, and utilized empirical data were viewed as *being subjective, tentative, creative, and empirically-based*, respectively. Four of the teachers, in the first teaching session, assumed that students would pick up target aspects of the NOS only by being exposed to situations of *doing NOS* without having students discern their *doing NOS*. The teachers' perception on *doing NOS* supports the idea that they saw aspects of the NOS in students' doing activities. However, the awareness of their implicit teaching coupled with *doing NOS* does not necessarily lead to explicit and reflective

NOS instruction. In the second teaching session four teachers still remained at Level 2. Even in the third teaching session, one teacher falls into a didactic style. When compared with Level 3 lessons, Level 1 and 2 teacher groups need more knowledge on how to make it explicit and reflective.

In conclusion, having informed views of the NOS is necessary but not sufficient to enable teachers to address the NOS instructionally. It was evident that teachers had the NOS understanding and had internalized the importance of teaching their students about some aspects of the NOS. However, this did not translate into effective and meaningful NOS instruction in their classrooms. They need more support to enable them to translate their views and intentions into explicit NOS instruction. They also needed support in externalizing their tacit NOS understandings and then in translating those understanding into classroom practice.

Recommendations

The recommendations by researcher are:

1. The recommendations from the research findings

1.1 Policy recommendation

The results of the this study indicated that science teachers need NOS specific support and professional development that goes beyond pre-service education into in-service settings. The Ministry should promote development of a system for science teachers, including production and further refinement. The Ministry should, in this regard, take a supervisory and co-coordinating role so that the institutions responsible for production and development of teachers shall be ready and capable of preparing new teachers and continually developing in-service personnel.

1.2 Performance recommendation

The results of this study indicated that there are two critical changes that need to be performed in order to implement explicit and reflective NOS instruction. First, teachers need to realize that explicit is better than implicit instruction. Second, teachers need to be aware that a student-centered approach is better than a didactic approach.

2. The recommendations for the further research

2.1 This research focused on developing teachers' understanding and instruction of the NOS. 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 NOS and students' achievements in studying science.

2.2 The follow-up study should prolong at least one semester after the professional development finished for tracing teachers' retention of teaching nature of science.

2.3 A researcher should emphasize on helping teachers to see the relationship between their views of science and their science instruction and the relationship between the NOS and the objectives of science teaching and learning in accordance with the science curriculum. The participants should have opportunities to clarify their existing views of science and their teaching. They should compare them with the specific concepts and instructional approaches of the NOS, so the participated teachers could reconstruct and make decisions to adjust their existing ideas and practice.

2.4 According to teachers' needs and suggestions, there should be modeling of the NOS instruction within teachers' classrooms or microteaching with real students from teachers' classes. Participants 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 NOS as in modeled lessons to other classroom contexts.

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APPENDIX

APPENDIX A

Example of a Science Story Activity
in Professional Development Program

มารู้จักจักรวาลของเรา

ก่อนเริ่มทำกิจกรรมนี้

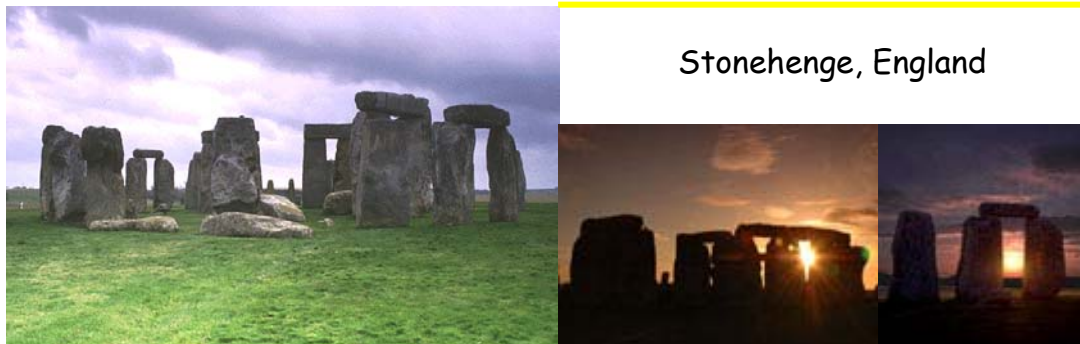
เมื่อคุณมองดูท้องฟ้ายามค่ำคืน คุณคิดถึงอะไร?

- มีสิ่งมีชีวิตอื่นที่อยู่บนดาวดวงอื่นอีกหรือไม่
- ดาวดวงนี้มีอิทธิพลชีวิตเราจริงหรือไม่
- อื่นๆ



จัดลำดับแนวคิดเกี่ยวกับจักรวาล

การสังเกตดวงดาว: มีความเชื่อว่า Stonehenge เป็นเครื่องมือที่ถูกสร้างขึ้นมาเมื่อ 2000 ปีมาแล้ว เพื่อใช้ศึกษาการเคลื่อนที่ของดวงอาทิตย์และดวงจันทร์ และรูปกลุ่มเมฆนั้นเป็นกล้องโทรทรรศน์ใช้ศึกษาดวงดาวที่มีความทันสมัย และมีประสิทธิภาพกว่าเครื่องมือในยุคก่อนๆ มาก



หอสังเกตการณ์เยอร์คิส (Yerkes Observatory)
ที่ตั้งของกล้องโทรทรรศน์หักเหแสงที่ใหญ่ที่สุดในโลก



กล้องโทรทรรศน์สมัยใหม่

การจัดลำดับแนวคิดเกี่ยวกับจักรวาล



ผู้คนมักจะมองขึ้นดูท้องฟ้ายามค่ำคืนด้วยความสงสัย และพยายามหาคำอธิบายเกี่ยวกับสิ่งที่พวกเขาเห็นนั้น ซึ่งมีหลายแนวคิดที่ต่างจากความรู้ที่เรายอมรับกันในปัจจุบันอย่างมาก ในกิจกรรมนี้ เราจะมองจักรวาลตามนักคิด และนักวิทยาศาสตร์ 4 ท่าน ในช่วง 4000 ปีที่ผ่านมา จากกิจกรรมนี้ คุณจะเห็นว่าความเข้าใจในจักรวาลของพวกเขาได้เปลี่ยนแปลงไปอย่างไร?

1. ตัดรูป 4 ตัวละคร (นักคิด และนักวิทยาศาสตร์) และบัตรคำต่างๆ
2. จับคู่ระหว่างข้อความกับบุคคลที่คุณคิดว่าเขาน่าจะเป็นผู้กล่าวข้อความนั้น เมื่อทำเสร็จแล้ว แต่ละตัวละครควรมี 1 คำกล่าวที่เกี่ยวกับหัวข้อต่อไปนี้:
 - ดวงอาทิตย์ และดาวเคราะห์
 - ขนาดของจักรวาล
 - จุดศูนย์กลางของจักรวาล
 - วิธีการศึกษาวิทยาศาสตร์

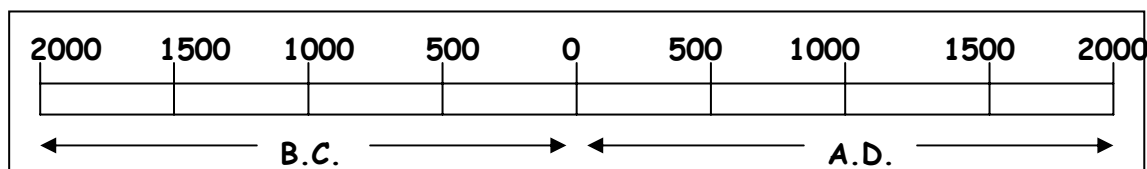


ตัวช่วย

การจับกลุ่มคำพูดแต่ละอย่างไว้ด้วยกันก่อนอาจจะช่วยให้ทำกิจกรรมนี้ได้ง่ายขึ้น ตัวอย่างเช่น จัดกลุ่มของบัตรคำที่เกี่ยวกับดวงอาทิตย์และดาวเคราะห์ เกี่ยวกับว่าแนวคิดใดน่าจะเกิดขึ้นก่อน และคำกล่าวที่เป็นปัจจุบันมากขึ้น

3. วาดเส้นเวลา (timeline) บนกระดาษขนาดใหญ่ ติดชื่อบุคคลและคำกล่าวของพวกเขาให้ตรงกันลงในเส้นเวลาให้ครบถ้วน

ความแตกต่างของความเข้าใจเรื่องจักรวาลของแต่ละบุคคล



จักรวาลของพระเจ้าอัมมูราปี



ราชาอัมมูราปี
กรุงบาบิโลน เมื่อชีวิต
เมื่อประมาณ

1600 ก่อนคริสต์ศักราช

“เมืองที่เราสร้างใหญ่โต และมีอาหารบริบูรณ์พอสำหรับ
ทุกคนที่นี่ ฉันศึกษาดาวและโหราศาสตร์ สร้างตำนานที่
ยิ่งใหญ่ที่อธิบายถึงโลกและดวงดาว”

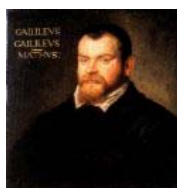
จักรวาลของปโตเลมี



ปโตเลมีมีเชื้อสายกรีก มีชีวิตอยู่ในช่วงประมาณ 200
ปีก่อนคริสต์ศักราช

“พวกเราได้ใช้ความคิดของเราในการค้นหาว่าจักรวาลว่า
น่าจะเป็นอย่างไร ชาวกรีกส่วนมากเชื่อในความคิดของ

จักรวาลของกาลิเลโอ



กาลิเลโออยู่ใน
กรุงโรม มีชีวิตอยู่ใน
ในช่วง ค.ศ.1600

“นักดาราศาสตร์ในโรมไม่เชื่อในความคิดของฉัน พวกเขา
ยังคงเชื่อในปโตเลมี และคิดว่าความคิดเมื่อ 1500
มาแล้วนั้นถูกต้อง ศาสนจักรจับฉันเข้าคุกเพียงเพราะ
ความเชื่อของฉันขัดกับคำสอนนั่นเอง”

จักรวาลของเอ็ดวิน ฮับเบิล



ฮับเบิลอยู่ที่
แคลิฟอร์เนีย
มีชีวิตอยู่เมื่อ ค.ศ.
1889- 1953

“ฉันได้เห็นไกลออกไปในอวกาศมากกว่าใครๆก่อนหน้านี้
ฉัน ความคิดของฉันทำให้นักวิทยาศาสตร์บางคน
ถึงกับช็อค ถึงอย่างไรเมื่อนักดาราศาสตร์ได้ตรวจสอบสิ่ง
ที่ฉันค้นพบ พวกเขาจะต้องยอมรับในที่สุด”

บัตรคำ



<p>ดวงอาทิตย์ และดาวเคราะห์</p> <p>ดวงอาทิตย์ ดาวเคราะห์ทั้งสี่ และดวงดาวทั้งหลายเคลื่อนที่รอบๆ เรา แต่ละดวงถูกยึดไว้เป็นทรงกลมคริสตัล ดวงจันทร์เป็นทรงกลมที่เล็กที่สุด ลำดับถัดไปคือ ดาวพุธ, ดาวศุกร์, ดวงอาทิตย์, ดาวพฤหัสบดี และดาวเสาร์</p>	<p>วิธีศึกษาวิทยาศาสตร์ของฉันทัน</p> <p>พวกเราได้ใช้การวัดอย่างชาญฉลาดและคำนวณ อย่างเช่น เส้นผ่าศูนย์กลางของโลก</p>
<p>ขนาดของจักรวาล</p> <p>ดวงดาวมากมายที่ฉันสามารถเห็นผ่านกล้องโทรทรรศน์ เป็นระยะทางห่างจากเราเป็นร้อยๆ เท่า จากดวงอาทิตย์</p>	<p>จุดศูนย์กลางของจักรวาล</p> <p>ฉันคิดว่าโลกคือ ทรงกลม ถูกตั้งแล้วที่นั่นแหละเป็นจุดศูนย์กลางของโลก ซึ่งเป็นการสร้างที่ยิ่งใหญ่ที่สุดของพระเจ้า</p>
<p>ขนาดของจักรวาล</p> <p>ด้านบนของโลกนั้นเปรียบเสมือนโดมขนาดใหญ่ ดวงดาวต่างๆ ทั้งหมดนี้ถูกยึดติดกับโดม นี่ก็คือสวรรค์ ซึ่งมันไม่ได้ห่างไกลจากโลกของเราเลย</p>	<p>จุดศูนย์กลางของจักรวาล</p> <p>จักรวาลประกอบด้วยกาแล็กซีต่างๆ มากมาย ซึ่งเริ่มต้นจากจุดเล็กๆ เดียวกัน และมีการขยายตัวของจักรวาลอยู่ทุกขณะ ที่เรียกว่า บิ๊กแบง (Big Bang)</p>
<p>ดวงอาทิตย์และดาวเคราะห์</p> <p>มีดาวเคราะห์ 9* ดวงประกอบเป็นระบบสุริยะ ดวงอาทิตย์ ก็เป็นดาวธรรมดาหนึ่งดวง มันอยู่ใกล้กับขอบของ กาแล็กซีเรา ซึ่งมีดาวเป็นพันล้านดวง ดวงดาวที่อยู่ใกล้ที่สุดอยู่ห่างออกไปหนึ่งล้านเท่าจากดวงอาทิตย์</p> <p>* ปัจจุบันดาวเคราะห์มีจำนวน 8 ดวง</p>	<p>ขนาดของจักรวาล</p> <p>ดวงดาวทั้งหลายเคลื่อนที่รอบโลกซึ่งติดอยู่กับทรงกลมขนาดใหญ่เกิดเป็นคริสตัล ซึ่งเป็นหลายเท่าห่างออกไปจากดวงอาทิตย์</p>

บัตรคำ



<p>วิธีศึกษาวิทยาศาสตร์ของฉัน</p> <p>ฉันสร้างกล้องโทรทรรศน์อันแรกครั้งแรก และพัฒนาจนกระทั่งมีกำลังขยายได้ถึง 32 เท่า ใช้ส่องดูดาวบนท้องฟ้า ได้พบความจริงว่าผิวของดวงจันทร์ไม่เรียบอย่างที่คิด และพบว่าดาวพฤหัสบดีมีดวงจันทร์เป็นบริวาร 4 ดวง</p>	<p>ดวงอาทิตย์ และดาวเคราะห์</p> <p>ในตอนกลางวัน ดวงอาทิตย์หมุนรอบโดมของสวรรค์ โดมถูกจับไว้โดยภูเขามากมายที่สุดท้ายของโลก และในตอนกลางคืน ดวงอาทิตย์เคลื่อนที่ได้โลกอันกลมตลอดภายใต้โลก</p>
<p>จุดศูนย์กลางของจักรวาล</p> <p>ฉันเชื่อตามโคเปอร์นิคัสว่าดวงอาทิตย์เป็นจุดศูนย์กลางของจักรวาล และโลกหมุนรอบดวงอาทิตย์ ฉันเลยโดนจองจำในคุกโดยคริสตจักรเพราะความเชื่อของฉัน</p>	<p>ขนาดของจักรวาล</p> <p>จักรวาลนั้นยิ่งใหญ่มากกว่าที่เราคิดนัก ดวงดาวทั้งหลายไม่ได้เป็นของกาแล็กซีเราทั้งหมด ยังมีอีกเป็นพันล้านกาแล็กซี</p>
<p>ดวงอาทิตย์ และดาวเคราะห์</p> <p>ฉันรู้ถึงลำดับของดาวเคราะห์ทั้งหกดวง ที่ใกล้ดวงอาทิตย์ที่สุด คือ ดาวพุธ, ดาวศุกร์, โลก, ดาวอังคาร, ดาวพฤหัสบดี, และดาวเสาร์ ดวงจันทร์หมุนไปรอบๆ โลก</p>	<p>วิธีศึกษาวิทยาศาสตร์ของฉัน</p> <p>พวกเราได้ทำการสังเกตดวงดาวต่างๆ ดังนั้นเราสามารถบอกได้ถึงอนาคต ตัวอย่างเช่น เราจะได้ลูกชายหรือไม่?</p>
<p>วิธีศึกษาวิทยาศาสตร์ของฉัน</p> <p>ฉันใช้กล้องโทรทรรศน์ขนาดใหญ่ และค้นพบว่ายังมีกาแล็กซีอื่นๆ อีกมากมายนอกเหนือจากเรา และมีการขยายตัวอยู่ทุกขณะ</p>	<p>จุดศูนย์กลางของจักรวาล</p> <p>ฉันคิดว่าโลกทั้งหมดนี้เป็นเพียงพื้นที่ราบอันกว้างใหญ่ ซึ่งล้อมรอบไปด้วยพื้นน้ำ ซึ่งเมืองของเรานั้นเป็นศูนย์กลางของโลก</p>

ความคิดหรือความเชื่อเปลี่ยนแปลงได้อย่างไร

1. ก. คำถามต่อไปนี้ คำถามใดที่สามารถตอบได้โดยวิทยาศาสตร์ และข้อใดวิทยาศาสตร์ยังไม่สามารถตอบได้?
 - จักรวาลเกิดขึ้นเมื่อใด?
 - จักรวาลมีจุดกำเนิดอย่างไร?
 - จักรวาลจะมีจุดสิ้นสุดหรือไม่?

ข. โคเปอร์นิคัสเป็นนักวิทยาศาสตร์สมัยใหม่คนแรกที่กล่าวว่าโลกโคจรรอบดวงอาทิตย์ แต่เขาได้ขอร้องให้ตีพิมพ์งานของเขาหลังจากที่เขาตายไปแล้ว ทำไมคุณถึงคิดว่าเขามีเหตุผลใดที่ต้องทำเช่นนั้น?

ค. ช่วงของโคเปอร์นิคัสต่างกับช่วงเวลาของกาลิเลโอ ที่ผู้คนทุกวันนี้สามารถยอมรับความรู้วิทยาศาสตร์ใหม่ๆ เกี่ยวกับจักรวาล และยังคงเชื่อในพระเจ้า ใช้คำตอบของท่านในข้อ ก. มาอธิบายความเป็นไปได้
2. พระเจ้าฮัมมูราบิ และปโตเลมี มีความเชื่อที่แตกต่างอย่างมากเกี่ยวกับจักรวาลกับนักดาราศาสตร์ปัจจุบัน
 - ก. คุณคิดว่าทำไมพวกเขาถึงไม่ได้ค้นพบสิ่งเดียวกับที่เราารู้ยู่ตอนนี้?
 - ข. ทำไมจึงใช้เวลาเป็นพันปี กว่าความเข้าใจจะพัฒนาจนถึงทุกวันนี้?
 - ค. “ความคิดของเราปัจจุบันเกี่ยวกับจักรวาลจะต้องถูกต้อง มันจะไม่มีเปลี่ยนแปลง” คุณเห็นด้วยกับคำกล่าวนี้หรือไม่? อะไรเป็นข้ออ้างอิง/หลักฐานจากประวัติศาสตร์?

ความคิดหรือความเชื่อเปลี่ยนแปลงได้อย่างไร

3. ลองจินตนาการว่าสันตะปาปาเซนต์อากุสตินัส เพราะว่าเขากล้าทำทนายที่จะพูดว่าโลกโคจรรอบดวงอาทิตย์ ศาสนจักรเชื่อว่าโลกนั้นหยุดนิ่ง และดวงอาทิตย์โคจรรอบโลก นี่คือนจุดที่บทสนทนาเริ่มต้น เขียนว่าคุณคิดว่าเหตุการณ์จะดำเนินต่อไปอย่างไร

สันตะปาปา: “เอาเป็นว่า ถ้าคุณพูดถูก และโลกนั้นหมุนรอบดวงอาทิตย์ ฉันควรจะตั้งรู้สึกเวียนศีรษะ และถ้าโลกหมุนจริง ฉันก็ต้องหลุดออกไปจากโลกแล้วละ แล้วคุณจะอธิบายเรื่องเหล่านี้ได้อย่างไร?”



4. ลองจินตนาการว่าคุณกำลังเดินทางย้อนกลับไปในอดีตเพื่อที่จะชักนำพระเจ้าฮัมมูราบิเกี่ยวกับความคิดอันทันสมัยของคุณ ของสิ่งใดที่คุณอยากจะทำติดตัวไปด้วยไว้เป็นหลักฐานช่วยคุณในการทำให้ท่านเชื่อ?

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ที่มา: PRI Sheffield Hallam University. 2001. *Pupil Researcher Initiative Ideas and Evidence*. (CD-ROM). Sheffield Hallam University.

เสมือนเป็นคำยืนยัน กาลเวลาเปลี่ยนไป อะไรที่ไม่คิดว่าจะเกิด ก็เกิดขึ้นได้ทั้งนั้นล่าสุดสมาคมดาราศาสตร์สากลได้ลงมติให้ตัด ดาวพลูโตออกจากสถานะดาวเคราะห์



จากที่เคยเรียนมาตั้งแต่เด็กๆ ดาวเคราะห์รอบโลกมีทั้งหมด 9 ดวง ก็ต้องเปลี่ยนตำราใหม่ เหลืออยู่แค่ 8 ดวงเท่านั้น ท่องกันใหม่

ดาวพลูโตถูกค้นพบในปี พ.ศ. 2473 โดยบังเอิญ มีการคำนวณหาตำแหน่งดาวเคราะห์ดวงใหม่ถัดจากดาวเนปจูน โดยใช้ฐานข้อมูลการเคลื่อนที่ของดาวยูเรนัส และดาวเนปจูน แต่ไม่ประสบความสำเร็จ จนกระทั่ง ไคลด์ ทอมบอห์ (Clyde Tombaugh) แห่งหอดูดาว โลเวล ในมลรัฐแอริโซนา ได้ทำการสำรวจท้องฟ้า และพบดาวพลูโตในที่สุด และถือว่าดาวพลูโตเป็น ดาวเคราะห์ดวงที่ 9 ที่อยู่ห่างจากดวงอาทิตย์มากที่สุด และเป็นดาวเคราะห์ดวงเล็กที่สุด เป็นเวลา 76 ปี นับแต่ พ.ศ. 2473-2549



ไคลด์ ทอมบอห์
ผู้ค้นพบดาวพลูโต

หลังจากได้ค้นพบดาวพลูโตแล้ว

นักวิทยาศาสตร์ยังคงถกเถียงกันว่า ขนาดของ ดาวพลูโต ขนาดของดาวพลูโตเล็กเกินกว่าที่จะ ครอบงวนวงโคจรของดาวเคราะห์ดวงอื่นได้ จะต้องมิดาวเคราะห์ดวงอื่นที่มีขนาดใหญ่กว่า

จึงจะครอบงวนดาวเนปจูนได้ ดังนั้นการค้นหา ดาวเคราะห์ X จึงมีขึ้นต่อไป แต่ก็ไม่มีสิ่งใดถูกค้นพบเพิ่มเติม จนกระทั่งยานวอยเอเจอร์ 2 ได้ข้อมูลด้านมวลสารของดาวเนปจูนเพิ่มเติม ข้อถกเถียง ดังกล่าวจึงหมดไป โดยไม่จำเป็นต้องมิดาวเคราะห์ดวงที่ 10

เมื่อวันที่ 24 สิงหาคม พ.ศ. 2549 ที่ประชุมสหพันธ์ดาราศาสตร์สากล ที่กรุงปารีส สาธารณรัฐเช็ก ซึ่งประกอบด้วยนักดาราศาสตร์กว่า 2500 คนจาก 75 ประเทศทั่วโลก ได้มีมติกำหนด นิยามใหม่ของดาวเคราะห์ ส่งผลให้ดาวพลูโตถูกปลดออกจากการเป็นดาวเคราะห์ในระบบสุริยะ คงเหลือดาวเคราะห์เพียง 8 ดวง เนื่องจากดาวพลูโตไม่สามารถควบคุมแรงดึงดูดและวงโคจรของสิ่ง ต่างๆ ที่อยู่รอบระบบสุริยะ และให้ถือว่าดาวพลูโตเป็น ดาวเคราะห์แคระ ซึ่งมีลักษณะคล้ายกับวัตถุขนาดเล็กในระบบสุริยะ และวัตถุในระบบสุริยะ (นอกจากดวงอาทิตย์) ได้ถูกจัดใหม่เป็น 3 ประเภท คือ คือ ดาวเคราะห์ ดาวเคราะห์แคระ และวัตถุขนาดเล็ก ในระบบสุริยะ



APPENDIX B

Results of Professional Development Program Evaluation

Criteria of the Professional Development Program Evaluation

1. The appropriateness evaluation of the draft program

The appropriateness level of each statement is ranged as following:

The appropriateness level	Scale value (points)
Very high level	5
High level	4
Moderate level	3
Low level	2
Very low level	1

The data from the draft evaluation form is analyzed by calculating the mean scores and assigned weightings as follows:

Mean scores	Appropriateness level
4.50-5.00	Very high
3.50-4.49	High
2.50-3.49	Moderate
1.50-2.49	Low
1.00-1.49	Very low

If the draft program evaluated by the experts has the level of appropriateness higher than 3.50, it means that the draft program is appropriate.

2. The consistency evaluation of the draft program

The consistency of the draft program will be analyzed by calculating Index of Item Objective Consistency (IOC). The range is assigned weightings as follows:

The consistency level	Scale value (points)
Consistent	+1
Not sure	0
Inconsistent	-1

The data from the program evaluation form is analyzed to find the Index of Item Objective Consistency (IOC) using the following formula:

$$IOC = \sum R / N$$

IOC means Index of Item Objective Consistency

$\sum R$ means Summation of experts' opinion marks

N means number of experts

If the Index of Item Objective Consistency (IOC) is higher than 0.5, it means the components of the program have internal consistency.

The Result of the Appropriateness Evaluation of the Professional Development Program

Items	Mean (n=5)	SD	Level of appropriateness
1 The principles of the program are appropriate for implementation.	4.6	0.49	Very high
2 The principles of the program are relevant to the needs of the science teachers.	4.4	0.49	High
3 The objectives of the program are clear.	4.2	0.40	High
4 The objectives of the program are feasible and practical.	4.4	0.49	High
5 The contents of the program are appropriate to secondary science teachers.	5	0.00	Very high
6 The contents of the program are feasible and practical.	4.8	0.40	Very high
7 The content structure in each workshop meets the objectives.	4.4	0.49	High
8 The contents are suitable for the teacher learning	4.8	0.40	Very high
9 The duration of the implementation is suitable.	4.2	0.40	High
10 Learning activities are appropriate to secondary science teachers.	4.4	0.49	High
11 Learning activities encourage active learning approach	4.6	0.49	Very high
12 The teaching-learning processes are appropriate for the program contents.	5.0	0.00	Very high

Continued

The Result of the Appropriateness Evaluation of the Professional Development Program (continued)

Items	Mean (n=5)	SD	Level of appropriateness
13 Instructional media and learning material are appropriate to science teachers.	4.2	0.40	High
14 Instructional media and learning material are appropriate for the teaching-learning processes.	4.2	0.40	High
15 Instructional media and learning material are suitable for the content.	4.6	0.49	Very High
16 Instructional media and learning material encourage learning.	4.8	0.40	Very High
17 Composition of the program is suitable.	4.2	0.40	High
18 Time allocation in each learning unit is appropriate for learning of the teachers.	4.0	0.00	High

The Result of the Consistency Evaluation of the Professional Development Program

Items	IOC	Level of consistency
1 The principles of the program with the objectives of the program.	1.0	consistency
2 The principles of the program with the content of the program.	1.0	consistency
3 The principles of the program with the teaching-learning processes.	0.8	consistency
4 The objectives of the program with the content of the program.	1.0	consistency
5 The objectives of the program with the teaching-learning processes.	1.0	consistency
6 The workshop plans and time allocation for implementation.	0.8	consistency
7 The content and activities in each workshop.	1.0	consistency
8 The content of the program with the teaching-learning processes.	1.0	consistency
9 The content of the program with the instructional materials.	1.0	consistency
10 The content of the program with the assessment and evaluation	0.8	consistency
11 The teaching-learning processes with the instructional materials.	1.0	consistency
12 The teaching-learning processes with the assessment and evaluation.	1.0	consistency

APPENDIX C

Results of Teachers' Responses to Five-point Likert Scale
to the Nature of Science Questionnaire

Results of Teachers' Responses to the Five-point Likert scale of the Nature of Science Questionnaire after Attending the Program

Statements	Amount of teachers' agreement				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1 Scientists have no idea of the outcome of an experiment before they do it.	-	-	-	2	13
2 All scientific ideas are discovered and tested by controlled experiment.	-	-	-	3	12
3 The social system imposes some restrictions on openness in technology.	14	1	-	-	-
4 Everyone can exercise them in thinking scientifically about many matters of interest in everyday life.	9	6	-	-	-
5 Imagination and creativity are not be used in coming up with hypotheses and theories.	-	-	-	3	12
6 Scientific method is the power tool that scientists have to follow its steps for the true knowledge.	-	-	-	5	10
7 For most major ideas in science, there is much experimental and observational confirmation; therefore, unlikely to change greatly in the future	10	5	-	-	-
8 There are many matters that cannot usefully be examined in a scientific way.	10	5	-	-	-
9 Because of reliance on evidence, science value is placed on the development of better instruments and techniques of observation.	8	7	-	-	-
10 Scientific research is economically and politically determined.	10	5	-	-	-
11 When social scientific issues occurred, only scientists or group of professionals take part to make decision.	-	-	-	11	4

Results of Teachers' Responses to the Five-point Likert scale of the Nature of Science Questionnaire after Attending the Program (continued)

Statements	Amount of teachers' agreement				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
12 Scientists assume that there is no way to secure complete and absolute truth. Increasingly accurate approximations can be made to account for the world and how it works.	5	10	-	-	-
13 Some scientists work in teams, and some work alone, but they need to communicate their scientific results and require peer review.	2	13	-	-	-
14 Scientific concepts do not emerge automatically from data, but scientists make inference from that data.	10	5	-	-	-
15 The best way to prepare to become a scientist is to master the scientific body of knowledge available in the fine texts.	-	-	-	5	10
16 It is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered.	4	11	-	-	-
17 Scientists are not influenced by personal expectation/beliefs and prior knowledge. When scientists make arguments, their personal bias does not have an influence.	-	-	-	11	4
18 Science assumes that the universe is a single system in which the basic rules are everywhere the same. Knowledge gained from studying one part of the universe is applicable to other parts.	2	13	-	-	-

Results of Teachers' Responses to the Five-point Likert scale of the Nature of Science Questionnaire after Attending the Program (continued)

Statements	Amount of teachers' agreement				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
19 Science is a process for producing knowledge. Science education should be more about the learning of scientific processes than the teaching of scientific facts.	11	4	-	-	-
20 Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanation.	7	8	-	-	-
21 Science can completely explain the world and how it works.	-	-	-	10	5
22 Scientific theories describe a real external world which is independent of human perception.	-	-	-	1	14

APPENDIX D

Example of Some Items in an Open-ended the Nature of Science Questionnaire

Example of Some Items in an Open-ended the Nature of Science Questionnaire

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion)? Please provide example for supporting your idea.
2. What is experiment?

Does the development of scientific knowledge require experiments?

 - If yes, explain why. Give an example to defend your position.
 - If no, explain why. Give an example to defend your position.
3. Does the development of scientific knowledge require experiments?
 - If you believe that scientific theories do not change, explain why. Defend your answer with examples.
 - If you believe that scientific theories do change: (a) Explain why theories change? (b) Explain why we bother to learn scientific theories? Defend your answer with examples.
4. Science textbooks often represent the atom as a central nucleus made up protons (positive charged particles) and neutrons (neutral particles) with electrons (negative charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?
5. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the Earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to the same set of data to derive their conclusions?

6. Some claim that science is infused with social and cultural assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

- If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.

- If you believe that science is universal, explain why. Defend your answer with examples.

7. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

- If yes, then at which stages of the investigations you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.

- If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Example of Some Items in an Open-ended the Nature of Science Questionnaire
(Annotation Guide of Some Items)

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion)? Please provide some examples for supporting your idea.

The desired response should refer to reliance on data from the natural world (empirical basis), systematic or organized approach to collection of data. It is also common for respondents to focus on the specific subject matter or objects of science' attention (this is where an interview can help get answers to what you really want to know about here)

Respondents are likely to incorrectly state that science follows a single method (the scientific method) and that science is a totally objective endeavor. They most likely will not include that alternative to these views, but the incorrect views are commonly included.

4. Science textbooks often represent the atom as a central nucleus made up protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

The focus here is on observation and inference and emphatically nature of science. A sophisticated, but uncommon answer would include that scientists have some data about atom and have inferred from this data what defined as “atom” looks like.

This question focuses on the roles of observation and inference in science. The desired answer would include that scientists have some data, but have inferred from this data what atoms look like.

Answers to this question may allow the researcher to determine whether a respondent understands that the development of science knowledge (via inferences) involves human creativity and subjectivity.

Occasionally, respondents give a percentage for how certain they think scientists are (i.e. scientists are 80% sure of how an atom looks) reflecting their views of the tentativeness of science.

5. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the Earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to the same set of data to derive their conclusions? Please provide some examples for supporting your idea.

This question reflects respondents' views about the subjective and tentative nature of science. The desired response would be that different scientists bring different backgrounds and different biases to the interpretation of data.

It is important to discern whether the respondent understands that different interpretations do not necessarily mean that someone is right and someone is wrong.

7. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

- If yes, then at which stages of the investigations you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.

- If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

A. If NO, explain why.

The desired answer here is "YES" and most respondents will answer this way. However, part B will give you more information about the adequacy of respondents' beliefs.

B. If YES, in what part of their investigations (planning, experimenting, making observations, analyzing data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

Most respondents will only understand, or at least say, that scientists use their creativity and imagination in the planning of investigations. Few will tell you that scientists use creativity and imagination during an experiment/investigation and in the interpretation of data and reporting of results.

This question relates back to respondents' understanding of why science is tentative and how creativity, subjectivity and inference permeate all of science.

APPENDIX E

Examples of Data Cross Checking of Teacher's
Conception of the Nature of Science

Examples of Data Cross Checking of Teacher's Conception of the Nature of Science

The nature of science aspect	Rating scales		Open-ended findings	Interview
	NOS item	responses		
Empirical basis Scientific knowledge is on empirical basis. Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models for most major ideas in science; there is experimental and observational confirmation.	7. For most major ideas in science, there is much experimental and observation confirmation and therefore unlikely to change greatly in the future.	Agree	Item 1* Science is the study about nature and we apply that knowledge for use in the good way. Science consists of principle and logic. Scientific knowledge is testable and has evidence or data for its confirmation. But the studies in other disciplines are the study of belief, practice, cultural, political. There are also the scientific knowledge integrated in these disciplines.	Scientists always record the results of experiment and observation – they usually want to explain those results in terms of a general theory... that they (scientists) have to make sure about their findings by accumulating as much as information or evidence before announcing to the public.
	9. Because of reliance on evidence, science value is placed on the development of better instruments and techniques of observation, and findings of any one investigation or group are usually checked by others.	Strongly agree		

*Item 1: What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion)? Please provide some examples for supporting your idea.

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