THE DEVELOPMENT OF BANGLADESHI SCIENCE TEACHERS' CONCEPTIONS OF NATURE OF SCIENCE

MD. ZIAUL ABEDIN FORHAD

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
(SCIENCE AND TECHNOLOGY EDUCATION)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2013

Thesis
entitled

THE DEVELOPMENT OF BANGLADESHI SCIENCE TEACHERS' CONCEPTIONS OF NATURE OF SCIENCE

……...
Md.Ziaul Abedin Forhad
Candidate

………..
Asst. Prof. Khajornsak Buaraphan, Ph.D.
Major advisor

………...
Lect. Karnyupha Jittivadhna, Ph.D.
Co- advisor

....
Lect. Sutha Luealamai, Ph.D.
Co- advisor

....
Ass. Prof. Auemphorn Mutchimwong, Ph.D
Acting Dean
Faculty of Graduate Studies
Mahidol University

..……..
Lect. Namkang Sriwattanarothai, Ph.D.
Program Director
Doctor of Philosophy Program in
Science and Technology Education
Institute for Innovative Learning
Mahidol University

Thesis
entitled

THE DEVELOPMENT OF BANGLADESHI SCIENCE TEACHERS' CONCEPTIONS OF NATURE OF SCIENCE

was submitted to the Faculty of Graduate Studies, Mahidol University for the degree of Doctor of Philosophy (Science and Technology Education)
on
November 12, 2013

....
Md. Ziaul Abedin Forhad
Candidate

....
Lect. Tussatrin Wannagatesiri , Ph.D.
Chair

....
Asst. Prof. Khajornsak Buaraphan, Ph.D.
Member

....
Lect. Sutha Luealamai, Ph.D.
Member

....
Lect. Karnyupha Jittivadhna, Ph.D.
Member

....
Ass. Prof. Auemphorn Mutchimwong, Ph.D
Acting Dean
Faculty of Graduate Studies
Mahidol University

....
Assoc.Prof. Wannapong Triampo
Director
Institute for Innovative Learning
Mahidol University

ACKNOWLEDGEMENTS

All Praise to the Almighty God that I have been fortunate a lot throughout my Ph.D. study. My gratitude and appreciation will never be enough for my advisor Asst. Prof. Dr. Khajornsak Buaraphan who has guided me since the beginning of my Ph.D study and research. This dissertation would not have been possible without his continuous support, unlimited motivation and proper guidance. I will always be grateful to him as his enormous knowledge headed me in all the time of the research and writing this thesis. I owe my gratitude to him as His enthusiastic and energetic support directed me to complete this study. His insightful discussions, suggestions and encouragements delighted me, energized me and kept me going on every time, especially whenever I was stuck. I've learnt from him, not only the scientific research but also the novel ways of being a mentor and guide others. I could not have imagined having a better advisor and mentor for my Ph.D. study.

I would like to express my sincere gratitude to the rest of my thesis committee: Dr. Karnyupha Jittivadhna and Dr. Sutha Luealamai, for their insightful comments, and suggestions throughout the, thesis writing. My Special thanks to Dr. Tussatrin Wannagatesiri for accepting to be the chair of the thesis committee.

I would like to thank Assoc.Prof.Dr.WannapongTriampo, Assoc.Prof.Dr.Bhinyo Panijpan, all other lectures and Instructors for their suggestions and teaching, all of my course mates, as well as all office staffs of Institute for Innovative Learning, especially Woranart Kongtrakoon (P'Bum) for their uncountable helps and supports during my study period.

The success of this thesis can be succeeded by the attentive support from three Bangladeshi educators who have translated the MOSQ in Bengali for me. I would like to acknowledge all of the head of the school in Dhaka, Bangladesh who has given me chance to conduct my research in their institutions

I will always be grateful to the entire respondents and participants, who have given their time and have been the sampling in this study, especially eagerly participated the workshop program and helped me to complete my study.

Finally, I would like to mention my parents and all other family members here, whose kind fullness and gratefulness is incomparable , for supporting me mentally, spiritually and financially both directly and indirectly and encouraging me throughout my life.

Md. Ziaul Abedin Forhad

THE DEVELOPMENT OF BANGLADESHI SCIENCE TEACHERS' CONCEPTIONS OF NATURE OF SCIENCE

MD. ZIAUL ABEDIN FORHAD 5136392 ILSE/D

Ph.D. (SCIENCE AND TECHNOLOGY EDUCATION)

THESIS ADVISORY COMMITTEE: KHAJORNSAK BUARAPHAN, Ph.D, KARNYUPHA JITTIVADHNA, Ph.D., SUTHA LUEALAMAI, Ph.D

ABSTRACT

In the present era, science and technology are rapidly and constantly changing. Students are expected to be scientifically literate individuals who have attained one essential characteristic, that is, understanding of the Nature of Science (NOS). Science teachers are builders of future scientific literate persons and responsible for developing an adequate informed understanding about the NOS in the students they teach. The basic requirement for teaching about the NOS for science teachers is that they must possess an adequate understanding about the NOS. The more science teachers understand about the NOS, the more they can deliver and develop students' understanding of the NOS. The main objectives of this study are: a) to explore Bangladeshi science teachers' conceptions of the NOS and b) to develop their NOS conceptions. (1)To serve the first objective, the Myths of Science Questionnaire (MOSQ), which consists of 14 items, was used to explore the Bangladeshi science teachers' conceptions of the NOS. The MOSQ can be used to explore four main aspects of the NOS: a) scientific knowledge; b) scientific inquiry; c) scientists' works; and d) scientific enterprise. (2)To address the second objective, an explicit-reflective workshop was created to help the participating science teachers develop their NOS conceptions. Both quantitative and qualitative data were collected for data analysis. The findings from the first phase revealed that the participants possessed uninformed conceptions of the NOS; this is comparable to the findings of other researches around the world that may impede the instruction of the NOS in science classrooms. The explicit-reflective NOS workshop designed for this study showed the positive effects of developing more informed conceptions of the NOS in the participants.

After the workshop, the participants realized their conceptions of the NOS and the importance of the NOS teaching and learning. They wish to see the explicit-reflective of the NOS workshop being conducted for other science teachers around the country.

KEY WORDS: NATURE OF SCIENCE / SCIENCE TEACHERS / BANGLADESH / BANGLADESHI SCIENCE TEACHERS

103 pages

CONTENTS

CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURES

CHAPTER I
INTRODUCTION

1.1 Background

The ultimate goal of science education is to cultivate "scientifically literate citizens" as of the continuous rising voice of science educational standardizing committees, science educational institutes as well as science educators for last several decades (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). To acquire adequate understanding of nature of science (NOS) is one of the most common and prominent attribute of a scientifically literate citizen. One major goal of science education is, therefore, helping students attain adequate understanding of NOS (Tao, 2003).

Initially, science teachers themselves should have adequate understanding of NOS, in order to help their students attain adequate understanding of NOS. Abd-El-Khalick and Lederman (2000) argued that. Science teachers are unable to address NOS in the classroom effectively without having sufficient informed views of NOS. Science teachers, having sufficient understanding of NOS can play as a role model to science, scientific attitudes and science related issues. (Murcia & Schibeci, 1999). For that reason, all science teachers are required to have proper understanding of NOS (Fouad Abd-El-Khalick & Lederman, 2000; Haider, 1999; Lederman, 1999; Tairab, 2001). Yet, many studies expose that, many science teachers have uncertain conceptions of NOS. For instance, in the Asian context, both Thai and Bangladeshi science teachers have unclear conceptions on NOS, Buraphan (2009) and Buaraphan and Sung-ong (2009) disclosed that a significant numbers of Thai science teachers holding alternative conceptions of NOS. Likewise, Sarkar (2010) found that, a majority of the Bangladeshi science teachers have uniformed and vague conceptions of NOS. therefore, it's one of the top priority task for science educators to take necessary steps to help science teachers achieve adequate understanding of NOS.

Bangladesh is located in the Southern Asia, bordering the Bay of Bengal, between Burma and India. The area of the country is 143,998 km sq and the coastline is 580 km. Bangladesh is in the tropical climate: mild winter (October to March); hot, humid summer (March to June); and humid, warm rainy monsoon (June to October). The population in Bangladesh was 163 millions. The Human Development Index of Bangladesh was 0.52 and the GDP per capita was $2,000 US. The Unemployment Rate was 5.00 %. The Literacy Rate of Bangladeshi people was 43.1%. The Political System is parliamentary democracy. The religions for Bangladeshi people were Muslim (83%), Hindu (16%), and other (1%). The official languages used are Bangla (also known as Bengali) and English.

Bangladesh was independent from Pakistan on 16 December 1971, which is known as Victory Day and commemorates the official creation of the state of Bangladesh. Since that time, several social groups have been developed and keep their long historical cultures. At now, there is cultural diversity in the Bangladeshi context that can be seen from different religious activities, festivals, music, dance, dramas, arts, crafts, folklore, folktale, local languages, and food. Several careers in Bangladesh are collectively influenced by ethnic groups such as Islam, Hinduism, Christianity, Buddhism, and etc. The majority of Muslim populations of Bangladesh celebrate two Eid a year. Males in the village or community will gather and perform a group Eid pray in the early morning of Eid-day and share food from cows, buffalos, or goats to relatives, friends, or neighbors.

There are three education systems in Bangladesh: a) general education, b) madrasa (religious) education, and c) technical-vocational education and professional education. Each of these is divided into five levels: primary (compulsory) (years 1-5), junior secondary (years 6-8), secondary (years 9-10), higher secondary (years 11-12), and tertiary (university) levels.

Before graduated from the secondary education (Grades 6-12), all students must take a national test being called “Board Exam” for the junior secondary, secondary, and higher secondary levels. The students in Grades 8 and 10 must take a national test for the Junior School Certificate (JSC) and the Secondary School Certificate (SSC), respectively. Normally, a students study junior and secondary levels in the same school and shift to a college and take a national test for Higher Secondary Certificate (HSC) after Grade 12. Even though many schools in Bangladesh are presently allowed by the Ministry of Education to teach until a college level (Grade 12), the excellent students are prefer to further their study in famous colleges as they believe that such colleges can influence their study in the university level.

Bengali and English (Language and literature), mathematics, general science, social science and religious study (Islam, Hindu, Buddha and Christian) are the compulsory subjects until the junior level. During Grades 9-12, students can choose to learn in the Science, Humanities, or Commerce fields. For the science field, the students can choose a specific field of science subject: physics, chemistry, biology, or higher mathematics. For the Humanities field, the students can choose one from these fields: history, geography, economics, or civics. For the Commerce field, the students can choose to learn specifically in accounting, introduction to business, or commercial geography. All fields must choose one optional subject from Agriculture studies, Computer study, or Arabic/ Sanskrit/ Pale.

After passing the SSC certificate in Grade 10, students can choose to go to colleges depending on their cumulative GPA. They further their study in colleges for two years and gain a HSC certificate. The students graduated from the Science field can further their study in the science, commerce or humanities majors. The students who passed in the commerce field can choose to study either the commerce or humanities majors in their college level. However, the humanities group students can study further in the humanities major only.

The National Curriculum and Textbook Board (NCTB) develops the curriculum as well as produce the standards textbooks and assessment papers. The Ministry of Education (MOE) is responsible for policy making. There is no NOS standard in the Basic Education Curriculum in Bangladesh.

There are 12 teachers training colleges and 48 primary teachers training institutes nationwide that aim to produce qualified primary and secondary teachers. In order to be a teacher in Bangladesh, one must possess a good subject back ground and earn education degree such as Bachelor in Education (B.Ed.). The literature about NOS in the Bangladeshi context is rare. One contemporary study was done by Sarkar and Gomes (2010). They found that a majority of the participating science teachers held uninformed conceptions about most of the target NOS aspects. Also, the teachers were not consistent in expressing their views to a particular NOS aspect and to its associated aspects. They finally suggested to do more research for better understanding about Bangladeshi teachers' mental models of NOS and their NOS classroom practices.

The National Curriculum and Textbook Board (NCTB) is responsible for developing curriculum, producing textbooks for primary, secondary and higher secondary levels. Ministry of Educations (MOE) of Bangladesh is responsible for setting policies. Two main policies in Section 11 regarding the goals of science education proclaimed by MOE in 2010 are: a) Students should be prepared in such a way that they should be able to acquire international leveled talent, knowledge and creativity; and b) Approach science education to students in such a way that science education is a part of combined education where science education has a deep relationship with technology education and humanity and each of these are interrelated to one another (MOE, 2010 p-37). However, NOS is not officially mentioned in the national policy.

Consequently, NOS is not explicitly mentioned in the Bangladeshi science curriculum. Up to this, there is no teacher education program to prepare pre-service teachers attains sufficient understanding of NOS. In addition, there is no teacher professional development program or workshop aimed to help in-service teachers improve their NOS conceptions.

The study about NOS in the Bangladeshi context is rare. Luckily, there are many science educators, who pursue their higher degree abroad, do research focusing on NOS. Anyway, there is no study about developing Bangladeshi science teachers' conceptions of NOS. Consequently, this study aims to explore the Bangladeshi science teachers' conceptions of NOS and develop their NOS conceptions by using an explicit-reflective NOS workshop. The uttermost objective is to improve the understanding of NOS of Bangladeshi science teachers and develop their ability to deliver overall science to the students that will cultivate scientifically literate citizens.

It potentially leads to a proposal for policy makers and curriculum developers about the revision of science curriculum embedding NOS.

1.2 Research Objectives

The objectives of this study are three folds.

a) To explore the Bangladeshi science teachers' conceptions of NOS
b) To develop the explicit-reflective NOS workshop helping the Bangladeshi science teachers develop their NOS conception, and
c) To explore the effects of the explicit-reflective NOS workshop on the Bangladeshi science teachers' development of NOS conception?

1.3 Research Questions

There are two research questions guiding this study.

a) What are the Bangladeshi science teachers' conceptions of NOS?
b) What are the effects of the explicit-reflective NOS workshop on the Bangladeshi science teachers' development of NOS conception?

CHAPTER II
LITERATURE REVIEW

The literature review is divided into four main parts: a) definition of NOS, b) importance of NOS, c) science teachers' conceptions of NOS, d) development of science teachers' conceptions of NOS, and e) NOS in the Bangladeshi context.

2.1 Definition of NOS

Although a significant number of studies related to NOS had been conducted during last several decades, a consensus, universal idea of NOS is not reached. The definition and components of NOS are varied according to the perspectives and focuses of the researchers NOS construct is diverse and fuzzy. There is no single, universal conception of NOS. As Schwartz and Lederman (2002) stated, "there is not a single NOS that fully describes all scientific knowledge and enterprises" (p. 207). The complexity to describe NOS would have lifted from its multifarious concept, which blends numerous areas in concert. Lederman (1992) quoted that NOS comprehends several areas, particularly epistemology, which implies how scientific knowledge is brought forth, and the part of science. In addition, McComas, Clough, and Almazroa (1998) expressed that:

> NOS is a fertile hybrid arena, which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavours. (p. 4).

According to Michael (2006), NOS includes the definition, process, and history of science, and the interaction between science and society. Moss (2001)has included some criteria as the key aspects of NOS, that is, asking researchable questions, collecting analyzable data, and communicating the results. Abd-El-Khalick, Bell, and Lederman (1998) and Miah (2001) mentioned NOS as the epistemology of science and the values and beliefs inherent in scientific knowledge. Moreover, NOS includes the development of scientific knowledge (Shiang, Lederman, & Norman, 2007). Furthermore, Weinburgh (2003) added that, science and scientific enterprise is not an individual endeavor rather, it's a collective human endeavor where people from all ages, sexes, races, cultures and nationalities engage in this enterprise and in addition to that science is evidence based not dependent to logic or faith.

NOS is a broader phenomenon without definite agreement or consensus idea. NOS is commonly used to describe epistemology of science and scientific knowledge. It also includes the values of scientific knowledge that are developed by the repetition and continuous discussion, thinking, and practice in both in individual and collaborative endeavors. Individual differences are related to and influenced those values. Thus, NOS is rooted component of science and varying from person to person.

Different aspects of NOS were elaborated more by subsequent studies. Most of the researchers agreed upon eight aspects of NOS, that is, scientific knowledge (SK) is tentative or changeable; SK is empirically based by depending on observations of the natural world), SK is subjective or theory-laden—it is partly the product of human inference, imagination, and creativity, SK is socio-culturally embedded, the distinction between observations and inferences, and the functions of, and relationships between scientific theories and laws (Foud Abd-El-Khalick et al., 1998)

From the analysis and synthesis of eight international science standard documents, McComas, Almazroa, and Clough (1998) proposed fourteen common aspects of NOS:

1) Scientific Knowledge is long lasting but "tentative as well.
2) Scientific knowledge depends mostly but not completely on empirical, "argument", logic and "skepticism".

3) No absolute solutions for scientific problem solving and no specific "step-by-step" ways in scientific methods.
4) Science tries to explain the "natural phenomenon".
5) Laws and theory have their own identity and theory will not transform to a law in spite of having further "evidence".
6) Science is the "contribution" of all cultural people around the world.
7) Every new inventions should be open to everyone and "clearly reported".
8) The works of scientist should be reproducible and they should have "accurate record" of it.
9) Observations are according to theory.
10) One of the most important characteristics of scientists are their creativeness or originativeness.
11) Sciences' history is inherited with "evolutionary and revolutionary" features.
12) Science is not apart from society and cultures but has relationship with them.
13) Science and technology are co-related and influenced by each other's and
14) Society and historical background has influence or impact on "scientific ideas".

Scientific Knowledge is long lasting but tentative as well; Scientific knowledge depends mostly but not completely on empirical, "argument", logic and "skepticism"; No absolute solutions for scientific problem solving and no specific "step-by-step" ways in scientific methods; Science tries to explain the "natural phenomenon"; Laws and theory have their own identity and theory will not transform to a law in spite of having further "evidence"; Science is the "contribution" of all cultural people around the world; Every new invention should be open to everyone and "clearly reported"; The works of scientist should be reproducible and they should have "accurate record" of it.; Observations are according to theory; One of the most important characteristics of scientists are their creativeness or originativeness;

Sciences' history is inherited with "evolutionary and revolutionary" features; Science is not apart from society and cultures but has relationship with them; Science and technology are co-related and influenced by each others; and Society and historical background has influence or impact on "scientific ideas".

According to *Science for all American*, the three key features of NOS are: a)Scientific world view: the world is understandable and science has limitation of answering all the questions; b)Scientific Inquiry: inquiry is generally logic- and empirical-based and includes imagination; and c) Scientific enterprise: NOS emphasizes the social and political aspects of science (Fouad Abd-El-Khalick & Lederman, 2000).

Buaraphan (2009) categorized science teachers' conceptions of NOS into four major groups: scientific knowledge, scientific method, scientists' work, and scientific enterprise.

2.1.1 Scientific Knowledge:

Hypotheses, Theories, and Laws

A number of studies revealed that, more than half of the science teachers cherishing uninformed conception regarding the hierarchical relationship between hypotheses, theories, and laws (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008; Haidar, 1999; Rubba & Harkness, 1993). According to them, a hypothesis becomes a theory as soon as it is proven correct. A theory becomes a law after it has been proved by many different people and has been around for a long time, it. Moreover, the status of the truth or correctness of hypotheses, theories, and laws was also linked with the availability or accumulation of supporting evidence (Dogan & Abd-El-Khalick, 2008). The conception that these constructs are different types of ideas was not grasped (Abd-El-Khalick & BouJaoude, 1997). Some of the in-service science teachers believed that theories were facts before being proven by experiment hence they are confused with scientific theory and a scientific fact. (Tairab, 2001, p. 246).

Tentativeness of Science

By using a static-dynamic split as well as considering the status of scientific knowledge, in-service science teachers can be categorized into two groups. The view of science of the first group among the science teachers is stable or having a static status, on the other hand, the view of the second group about science is tentative or having a dynamic status. According to the static-science group, for instance, 24.1% of science teachers demanded that science is a collection of facts or a body of knowledge that explains the world (Tairab, 2001). Hence, Scientific knowledge was considered as static (Behnke, 1961). As a result, the main objective of scientific research is, the maximum amount of data collection. (Craven, Hand, & Prain, 2002; Tairab, 2001). On the other hand, the science teachers commonly assumed in the tentativeness of scientific knowledge as of the dynamic-science group, (Dogan & Abd-El-Khalick, 2008). For instance, Lunn's study (2002) revealed that, four of five primary teachers believed that science is frequently developing to effectively give a full world-view, particularly some mysterious patterns in nature. So, science, scientific knowledge is tentative and can be renewed and changed in the present of the light of new knowledge and new proofs, evidence as well as facts.

Cumulative Knowledge

Most of the in-service science teachers intensely thought that scientific knowledge is aggregated and its progression depend comprehensively on the accumulation of evidences or increasing observation rather than changes in theory (Brickhouse, 1990; Haidar, 1999). Hence, scientific knowledge is a cumulative knowledge which was the uninformed conception that might be linked to their prominence of believe or perfection (Dogan & Abd-El-Khalick, 2008).

Scientific Model

One of the popular uninformed conceptions of most the science teachers regarding the NOS is 'Scientific models are copies of reality' (Dogan & Abd-El-Khalick, 2008). According to them, Scientific models, are copies of reality instead of human inventions (Abd-El-Khalick & BouJaoude, 1997) the reason behind their claim might be the scientists seems to be true or most of the scientific observations and/or research have shown them to be true (Dogan & Abd-El-Khalick, 2008). On the other hand, to many teachers, with constructivist views towards Scientific models, can distinguish the role of scientific models as scientists' best thinking or accomplished conjectures to symbolize the reality rather than rigorous duplications of knowledgeable phenomena (Haidar, 1999).

2.1.2 Scientific Method: Universal, Step-Wise Method

Science teachers generally perceived the scientific method as a universal step-by-step method (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008; Haidar, 1999). Science curriculum can be accredited for that, because, it presents the scientific method as a structure of steps to the students and all of the students have to followed precisely so as to reach specific outcomes (Haidar, 1999) or explicit scientific fact (Brickhouse, 1990). To most of the science teachers, scientist who follow a procedure - the steps of the scientific method in their investigations, are good scientists (Abd-El-Khalick & BouJaoude, 1997; Haidar, 1999).

2.1.3 Scientists' Work: Theory-laden Observation and Subjectivity

Subjectivity and objectivity, theory-laden and theory-free or value-laden and value-free are some of the most usual ambiguous views of the NOS. According to the most science teachers; subjectivity shows a major role in the development of science (Abd-El-Khalick & BouJaoude, 1997) since scientists' paradigms or worldviews can affect their scientific intellectual and decision-making (Lunn, 2002, p. 664). Still, many science teachers intensely believed in independence or objectivity in science, which is definitely grounded on value-free or theory-free observation. For instance, approximately half of science teachers detained the inadequate conception that the observation of scientists are not prejudiced by the theories that they retaining (Brickhouse, 1990; Dogan & Abd-El-Khalick, 2008; Haidar, 1999). Majority of the science teachers (71%) espoused the elevated view that the scientists' are far from their reference system and their rendering was nonsubjective (Abd-El-Khalick & BouJaoude, 1997; Rampal, 1992).

Creativity and Imagination in Science

Most of the science teachers believe that scientists must follow a fixed-step scientific method so they overlooked the scientist' creativity as well as the role of creative thinking and imagination in the construction of scientific inventions (Abd-El-Khalick & BouJaoude, 1997). For instance, Rampal's study (1992) revealed that there were less than 10% of science teachers who acknowledged the importance of creativity in scientists' work. In this case, 'creativity seems to be stereotypically dissociated from perceived scientific qualities' (p. 424).

2.1.4 Scientific Enterprise:

Social and Cultural Influences on Science

Majority of science teachers explicitly acknowledged the social and cultural influences on the scientific enterprise (Brush, 1989). For instance, Haidar (1999) and Rubba and Harkness (1993) indicated that nearly or more than half of the science teachers are influenced by social factors. Moreover, Tairab's (2001) study expressed that 79.6% of science teachers support that, society affects science and technology, and in turn science and technology affect society as well. Nevertheless, less than a quarter of science teachers considered that a scientist is influenced by social predetermines and governmental pressure during data collections or presenting information. The authoritative image of the scientist is conceived precisely to them. (Rampal, 1992).

Interaction between Science and Technology

Even though, it seems to be an easy task to recognize the interaction between science and technology in such ideas as science is the knowledge base for technology, and technology influences science advancement for the in-service science teachers (Rubba & Harkness, 1993). Still, distinguishing and differentiating between

science and technology is likely an unmanageable task for them (Rubba & Harkness, 1993). To them, an widely general uninformed conceptions about the relationship between science and technology is 'Technology is applied science' (Tairab, 2001).
Hence, this study, NOS is delimitated as consisting of four major components, which are, scientific knowledge, scientific method, scientists' work, and scientific enterprise.

2.2 Importance of NOS

Understand ing of NOS is regarded as one essential characteristic of scientifically literate person (AAAS, 1993; NRC, 1996). A scientific literacy (SL) is required for a personal decision making regarding scientific issue, a person having SL can make socio-economic decision making and engage in civil and cultural development scientifically and dynamically, scientific-problem solving and innovative development can be possible from a person with SL (Holbrook, J., & Rannikmae, M., 2007) Driver, Leach, Millar and Scott (1996) has argued that understanding of NOS is important for a scientific literate person to understand science, technology and handle these scientific phenomena and technological objects, to make a "informed decision-making" regarding socio scientific issue, one should have enough understanding on NOS. a scientific literate person should posses adequate understanding of NOS to accept the interdisciplinary influences of science on culture and society, Understanding of NOS direct a person to develop positive attitude towards moral value of the society. moreover, NOS understanding trigger a person to science learning. A scientific literate play a vital role in economic productivity, can generate scientific idea that can lead creativity for innovative discovery. science education develops a person's intellectual reasoning skill and scientific knowledge helps him to understand the fact of everyday world with logical, understandable clearer explanations a scientific literate become an expert of problem solver scientifically hence is helpful for himself, society, county a nations, as well as for the whole world. So, to make a scientific literate nation, need to make scientific literate person, to make a scientific literate person, need to teach the knowledge of science, its process its history its interactivity and relationship with society, need to teach the characteristics of science need to teach the Nature of Science.

Science teachers are, therefore, responsible for developing adequate understanding of NOS in all students they teach (Buaraphan & Sung-ong, 2009). To do that, first of all, science teachers must possess clear understanding of NOS, which they intend students to attain because they cannot teach what they do not understand (Lederman, 1992).

Although NOS is important, the literature shows that may science students or even science teachers have inadequate understanding of NOS. The following section illustrated this issue in detailed.

To make a scientific literate nation, it needs to make a society of scientific literate persons. One indispensable attribute of a scientifically literate persons is to have understanding of NOS (AAAS, 1993; NRC, 1996), which is needed for coping a variety of scientific and technological issues in the rapid changing world. In addition, Driver, Millar and Scott (1996) argued that understanding of NOS is important for a scientific literate person to understand science and technology and make an informed decision-making regarding socio-scientific issues. Also, they can make socio-economic decision making and engage in civil and cultural development scientifically and dynamically, scientific-problem solving and innovative development (Holbrook & Rannikmae, 2007).

Several studies confirmed that students' learning and illustration of their knowledge are directly reflected to, and mostly contributed by, their teachers' teaching. There is in a case for teaching and learning NOS also. The National Science Teacher Association (NSTA) elaborated and emphasized several aspects that science teachers should follow while teaching NOS. That is, science teacher should facilitate the students to learn history and philosophy and practice of science. They should also make clear conception between science and non-science to the students. They should act as a key role so that students can understand the all the main branches of science and they can be able to analyze any assertion derived from science. For this reason, teachers should prepare themselves completely and they should demonstrate that they have adequate knowledge of components, key aspects, and factors that influence NOS (NSTA, 2003).

One goal of science education is, therefore, cultivating adequate understanding of NOS in science students. Science teachers are, therefore, responsible for developing adequate understanding of NOS in all students they teach (Buaraphan & Sung-ong, 2009). To do that, first of all, science teachers must possess clear understanding of NOS, which they intend students to attain because they cannot teach what they do not understand (Lederman, 1992). Without sufficient internalizing of informed views of the NOS, science teachers cannot effectively address NOS in the classroom (Fouad Abd-El-Khalick & Lederman, 2000). Adequate understanding of NOS allows science teachers to model appropriate science-related behaviors and attitudes (Murcia & Schibeci, 1999). Accordingly, proper understanding of NOS is needed for all science teachers (Fouad Abd-El-Khalick & Lederman, 2000; Haider, 1999; Lederman, 1999; Tairab, 2001).

It is the major responsibility of science teachers to help their students developing adequate understanding of NOS to become a scientifically literate citizen. Hence, this study aims to create the professional Development Program to help in-service science teachers' develop their understanding of NOS and enhancing their ability to integrate NOS in their teaching effectively teaching NOS in their classrooms. This task will serve the ultimate goal of science educations in cultivating scientifically literate citizens.

Although NOS is important, the literature shows that may science students or even science teachers have inadequate understanding of NOS. The following section illustrated this issue in detailed.

2.3 Science Teachers' Conceptions of NOS

Teachers having informed understanding of NOS are capable of more effective teaching (Driver , Leach, Miller & Scott (1996). However, many previous researches revealed that, science teachers holding vague conceptions of NOS (Abd-El-Khalick, Bell & Lederman, 1998; Abd-El-Khalick and Lederman, 2000; Buaraphan &

Sung-ong, 2009; Cakiroglu, Dogan, Bilican Cavus & Arslan, 2009; Dogan Abd-El-Khalick, 2008).

Elaborately, Tairab (2001) revealed that science teachers had mixed view about science. Haider (1999) also found that Emirates teachers' had mixed views of NOS. The teachers’ NOS understanding were historically and religiously influenced. Supported by Dogan and Abd-El-Khalik (2008), Turkish science teachers' conceptions of NOS were interrelated with their regional, social, cultural as well as educational background (Dogan & Abd-El-Khalick, 2008; 1991) Gallagher (1991) found out that almost all participants possessed “unsettling” views of NOS. In addition, Moss (2001) found that NOS conceptions were resisted for change even though the participating teachers attended specific science courses.

In the Asian context, Buaraphan (2009) revealed that a majority of science teachers in Thailand held uninformed conceptions of NOS regarding eight aspects: a) scientific theories can be developed to become laws; b) accumulation of evidence makes scientific knowledge more stable; c) scientists are open-minded without any biases; d) scientific theories are less secure than laws; e) the scientific method is a fixed step-by-step process; f) science and the scientific method can answer all questions; g) a scientific model (e.g., atomic models) expresses a copy of reality; and h) science and technology are identical. Additionally, in the Bangladeshi context, Sarkar (2010) found that a majority of Bangladeshi science teachers have uniformed and vague conceptions of NOS, which were attributed to curriculum of as well as traditional teaching and learning approach. He attributed the fact to the curriculum of as well as traditional teaching and learning approach, The situation is similar to other Asian country like Thailand might be because of socio-cultural influence on learning and teaching environment. according to him , Bangladeshi science teachers possess informed conceptions in some NOS aspects not because they are educationally taught but because of their religious background For example, 'science can answer the questions' and the teachers of his study indicated informed view that science can't answer the questions which was reflected from their written expressions that science can't answer about Allah (God) and Angels, it's because more than ninety percent of the populations of Bangladesh are Muslim who believe in Islam. Moreover, Bangladesh is a developing country having conservative, man headed society. Not so long before, male students were encouraged to go to school (primary and secondary level) and college (higher secondary level) for study as long as their limited incomer family could support them and on other hand female were pulled behind for helping household work. Even though the situation is changing as lot in the municipal area but there are some rural area where people are cherishing their forefathers footsteps. Because of the poverty, children has to leave school and go to work field for income and support their family in many places of Bangladesh. One of the most over populated country in Asia having the lowest income level with the most competitive employment society, teaching job is very challenging .where a teacher has to take a heavy work load with tremendous pressure both physically and mentally, Moreover, almost all of the science teachers are engaged in after school as well as before school tutorial for extra or alternative earning. So he or she has a very little time and chance to think even for his own as well as for students' development regarding science teaching

As mentioned earlier, many science teachers held uninformed conceptions of NOS. The literature suggests various methods to help develop more informed conceptions of NOS as followed.

The uninformed conceptions of NOS may be arisen from the socio-cultural environment in the each country. In particular to the Bangladeshi context, although teachers are not educated about NOS, they possess some informed conceptions of NOS because of their religious background. In particular to the “Science can answer all questions” item, teachers indicated informed view of NOS that science cannot answer all questions especially the question about Allah (God) and Angels. More than 90% of the Bangladeshi populations are Muslim, who believe in Islam. The gender variable may also affect teachers’ NOS conceptions. Bangladesh is a developing country with the conservative, man headed society. Men are encouraged to go to schools in the primary, secondary, and university levels; while, women are left behind for helping household works. At present, this situation is changing especially in the municipal area, but in the rural area it is still true. Poverty also affects education. In the poor families, children are forced to leave schools and go to workforce to support their families. The low income additionally affects teaching science. A teacher has to take a heavy workload with tremendous physically and mentally pressure. After school time, almost all science teachers do a tutor business for extra earning. So, he or she has limited time to prepare or think about their teaching of science.

As mentioned earlier, many science teachers held uninformed conceptions of NOS. The literature suggests various methods to help develop more informed conceptions of NOS as followed.

2.4 Development of Science Teachers' Conceptions of NOS

Implicit approach uses generally instruction based on science process skill and or instruction on scientific inquiry activities (Abd-El-Khalick, 2000). In the early age of 1963, Klopfer and Cooley had attempted to improve NOS conceptions by including implicit instructional method on inquiry and process skills. Later, the similar studies were also conducted such as Rowe (1974), Gabel, Rubba and Franz (1977), Lawson (1982), and Haukoos and Penick (1983, 1985). They suggested that the development of understanding of NOS is a by-product of 'process skill', learning 'science content coursework, and 'doing science'. Similar subsequent researchers such as Haukoos and Penick (1983, 1985), Scharmann (1990), Scharmann and Harris (1992), Spears and Zollman (1977) claimed that, researchers who advocated the implicit approach for developing NOS conceptions, 'manipulated certain aspects of learning environment' while they try to help the teachers to develop their NOS conceptions (Abd-El-Khalick, 2000). However, some studies conducted by several researchers like Yager and Wick (1966), Tamir (1972), found that the implicit-NOS attempt was not successful. For example, Duschl (1990) and Lederman (1992) showed that students failed to acquire expected understanding of NOS.

There were several studies regarding developing science teachers' understanding of NOS (Abd-EL-khalick, 1998; Billeh and Hasan, 1975; Bloom, 1989; King, 1991; Scharmann and Harris, 1992). Abd-El-Khalick and Lederman (1998) found that the implicit approach could not effectively help the participating teachers develop NOS understanding because they retained their naïve NOS views. In sum, the implicit approach is less effective for developing the understanding of NOS because it emphasizes a cognitive learning outcome and think about NOS as a by-product of scientific investigations.

On the other hand, a number of studies aimed at developing teachers' view on NOS by the explicit-reflective approach. The success of explicit-reflective approach in relation to NOS conceptions is reported by many researchers such as Billeh and Hasan (1975), Hodson (1985), Kimball (1967, 1968), Klopfer (1964), Bethel and Lamb (1977), Meichtry (1995), Bianchini and Colburn (2000), and Akerson, Abd-El-Khalick and Lederman (2000).

Subsequent studies to improve NOS were conducted focusing on inquiry based instructions or and process skill. After words, Study conducted by several researchers like Yager and Wick (1966),Tamir (1972), found that this attempt was not successful. Duschl (1990) and Lederman (1992) shown that students failed to acquire expected desired understanding of NOS. Moreover, several attempts were taken to improve teachers' understanding on NOS time to time by Abd-EL-khalick (1998), Billeh and Hasan (1975), Bloom(1989), King (1991), Scharmann and Harris (1992). Abd-El-Khalick and Lederman (1998) found that researchers were unable to teach NOS "effectively" and desired result were not attained rather than retaining naïve views, the reason behind is, they were tough NOS implicitly. Moreover, criticisms were raised by several researchers related to the instrument used and assessment validity of implicit approach. From the reviewed study, researchers conclude that, implicit approach is less effective for at least two reasons, a) Developing the understanding of NOS by implicit approach works such as, learning NOS is a 'cognitive' learning outcome. And b) learners develop their conceptions of NOS as a 'by-product', by engaging scientific activities

Recent studies agreeing that NOS should be learnt or taught explicitly in science rather than indirect or by-product learning of science. For this reason, explicit-reflective approach is suggested by many researchers such as Abd-El-Khalick and Lederman (2000), Akerson, Abd-El-Khalick, and Lederman (2000), Craven, Hand and Prain (2002), and Kuchuk (2008).

Driver et al. (1996) suggested that NOS should not be regarded as an add-on of science content; rather, it should be tightly linked to the content taught. In addition, a number of NOS research (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000; Bartholomew, Osborne, & Ratcliffe, 2004; Cakiroglu, Dogan, Bilican, Cavus, & Arslan, 2009; Schwartz & Lederman, 2002) suggested that effective teaching about NOS must be conducted in an explicit-reflective manner, i.e., teachers make aspects of NOS an explicit part of classroom discourse and provide learners opportunities to reflect upon and explain their ideas about NOS.

Schwartz and Lederman (2002) described the explicit-reflective approach for teaching about NOS as:

> An *explicit* instructional approach intentionally draws learners' attentions to relevant aspects of NOS thorough instruction, discussion, and questioning that makes NOS visible in classroom instruction. …The *reflective* component involves the application of these tactics in the context of activities, investigations, and historical examples used in daily science instruction. Thus an explicit/reflective approach involves *purposeful* instruction of NOS through discussion, guided reflection, and specific questioning in the context of classroom science activities. (p. 207) [emphases in original]

Lederman, Schwartz, Abd-El-Khalick, and Bell (2001) emphasized that, in the explicit approach, NOS understanding must be intentionally planned for, taught, and assessed. Hanuscin et al. (2010) additionally elaborated four overarching criteria of explicit approach in teaching about NOS: a) teachers plan to teach a particular aspect of NOS; b) students are made aware of the target aspect of NOS; c) student are provided an opportunity to discuss and/or reflect on their ideas about the target aspect of NOS; and d) teachers elicit students' ideas about NOS before, during, or at the conclusion of the activity.

To line up with the global movement of NOS, National Curriculum and Textbook Board [NCTB] (1995) of Bangladesh has raised the flag of NOS in the secondary science curriculum with the objective of conveying the understanding of

NOS to the learners without taking any distinct step for the teachers who are the conveyer. As result, the teachers are lack behind of developing NOS understanding as well as the students' .Moreover, this issue was complexly forgotten as soon as it was introduced. Not even any notable researches have been conducted from its birth time in Bangladesh. Fortunately one or two Bangladeshi by birth but residing outside of the country are started to re-introduce the issue and trying to bring it under spot light again. However, there is no significant study conducted till now on the development of the Bangladeshi science teachers' conceptions of NOS. If the situation couldn't be handled immediately and appropriate stets for improving sciences teachers development of understanding of NOS won't taken then county will lose science educated people in the near future , the flow of science learning won't able to produce scientific literate, socio-economic development will be slow down and science illiteracy will start up and the county will be in backward.

This chapter illustrates the definition and importance of NOS, science teachers' conceptions of NOS, ways to improve NOS conceptions, and NOS in the Bangladeshi context. The literature shows that the Bangladeshi science teachers lack understanding of NOS. In addition, there is a lack of NOS study in the Bangladeshi context. If these situations are not handled properly and immediately, it may affect the production of scientific literate persons in the country that subsequently leads to slow scientific and socio-economic development. To cope with that, this study aims to a) explore Bangladeshi science teacher' conceptions of NOS; and b) to explore the effect of the explicit-reflective NOS workshop on the Bangladeshi science teacher' development of NOS conceptions.

CHAPTER III
METHODOLOGY

The study is divided into two main phases in order to answer to two research questions, that is, a) what are the Bangladeshi science teachers' conceptions of NOS? And b) what are the effects of the explicit-reflective NOS workshop on the Bangladeshi science teachers' development of NOS conception?

3.1 Phase 1: Science Teachers' Conceptions of NOS

The first phase is a survey research aimed to explore science teachers' conceptions of NOS. In this phase, the Myths of Science Questionnaire (MOSQ) (Buaraphan & Sung-ong, 2009) is used to explore are the Bangladeshi science teachers' conceptions of NOS. MOSQ consists of 14 items clustered into four main aspects of NOS, i.e., a) scientific knowledge (Items 1-4), b) scientific inquiry (Items 5-9), c) scientists' works (Items 10-11) and d) scientific enterprise (Items 13-14) as Figure 3.1

Directions: Please select the choice that best reflects your opinion and provide an explanation supporting your selection.

Statement	Opinion
1. Hypotheses are developed to become theories only	□ Agree □ Uncertain □ Disagree …………………………………......
2. Scientific theories are less secure than laws	□ Agree □ Uncertain □ Disagree …………………………………......
3.Scientific theories can be developed to become laws	□ Agree □ Uncertain □ Disagree ………………………………….....

Figure 3.1 The Myths of Science Questionnaire (MOSQ)

Statement	Opinion
4. Scientific knowledge cannot be changed	□ Agree □ Uncertain □ Disagree …………………………………......
5. The scientific method is a fixed step-by-step process	□ Agree □ Uncertain □ Disagree …………………………………......
6. Science and the scientific method can answer all questions	□ Agree □ Uncertain □ Disagree …………………………………......
7. Scientific knowledge comes from experiments only	□ Agree □ Uncertain □ Disagree …………………………………......
8. Accumulation of evidence makes scientific knowledge more stable	□ Agree □ Uncertain □ Disagree …………………………………......
9. A scientific model (e.g., the atomic model) expresses a copy of reality	□ Agree □ Uncertain □ Disagree …………………………………......
10. Scientists do not use creativity and imagination in developing scientific knowledge	□ Agree □ Uncertain □ Disagree …………………………………......
11. Scientists are open-minded without any biases	□ Agree □ Uncertain □ Disagree …………………………………......
12. Science and technology are identical	□ Agree □ Uncertain □ Disagree …………………………………......
13. Scientific enterprise is an individual enterprise	□ Agree □ Uncertain □ Disagree …………………………………......
14. Society, politics, and culture do not affect the development of scientific knowledge.	□ Agree □ Uncertain □ Disagree …………………………………......

Figure 3.1 (Continued)

To check the accurateness of translation from English to Bengali (Bangladeshi language), five experts were requested and engaged in the back translation method. The indistinct language was reviewed edited for more clarification.

Still, the questionnaire that distributed to the participants includes both English (original) and Bengali (translated) as Figure 3.2

The Myths of Science Questionnaire (MOSQ)

বিজ্ঞানেরজনশ্রুতি (রূপকথা)প্রশনমালা

Direction: Please select the choice that best reflects your opinion and provide an explanation supporting your selection.

দিকনির্দেশনা:

অনুগ্রহপূর্বকআপনারপছন্দনির্বাচনকরুনযাআপনারমতামতকেসবচেয়েবেশিপ্রতিফলিতকরেএবংএক টিব্যাখ্যাপ্রদানকরুনযাআপনারনির্বাচিতমতামতকেসমর্থনকরছে.

Statement (বিবৃতি/বক্তব্য)	Opinion (মতামত)
1.Hypotheses are developed to become theories only শুধুমাত্র তত্বে/সূত্রে পরিনত করার জন্যেই বৈজ্ঞানিক ধারণার উন্নতি বিকাশ করা হয়	☐ Agree / সম্মত/ অনুমোদন করি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা ………………………………………………
2. Scientific theories are less secure than laws বৈজ্ঞানিক তত্ব/ সূত্রসমূহ বৈজ্ঞানিক নিয়ম কানুনের চেয়ে কম সুরক্ষিত / নিরাপদ	☐ Agree / সম্মত/ অনুমোদন করি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা ………………………………………………

Figure 3.2 MOSQ in Bengali and English versions

Statement (বিবৃতি/বক্তব্য)	Opinion (মতামত)
3. Scientific theories can be developed to become laws বৈজ্ঞানিক তত্ত্বের/ সূত্রের উন্নতি সাধন ঘটিয়ে বৈজ্ঞানিক নিয়ম কানুনে পরিনত করা সম্ভব	☐ Agree / সম্মত/ অনুমোদনকরি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা …………………………………………
4.Scientific knowledge cannot be changed বৈজ্ঞানিক জ্ঞান পরিবর্তন করা যায়না।	☐ Agree / সম্মত/ অনুমোদন করি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা …………………………………………
5.The scientific method is a fixed step-by-step process বৈজ্ঞানিক পদ্ধতি একটি নিরধারিত ধারাবাহিক কার্যপ্রণালী।	☐ Agree / সম্মত/ অনুমোদন করি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা …………………………………………
6. Science and the scientific method can answer all questions বিজ্ঞান এবং বৈজ্ঞানিক পদ্ধতি সমস্ত প্রশ্নের উত্তর দিতে পারে ।	☐ Agree / সম্মত/ অনুমোদন করি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা …………………………………………
7.Scientific knowledge comes from experiments only বৈজ্ঞানিক জ্ঞান শুধুমাত্র পরীক্ষামূলক গবেষণা থেকেই আসে	☐ Agree / সম্মত/ অনুমোদন করি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা …………………………………………

Figure 3.2 (Continued)

Statement (বিবৃতি/বক্তব্য)	**Opinion (মতামত)**
8.Accumulation of evidence makes scientific knowledge more stable দলিল প্রমানের সমষ্টি বৈজ্ঞানিক জ্ঞানকে আরো বেশি স্থির/ মজবুত করে	☐ Agree / সম্মত/ অনুমোদন করি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা …………………………………………
9. A scientific model (e.g., the atomic model) expresses a copy of reality একটি বৈজ্ঞানিক মডেল (উদাঃ, পারমাণবিক মডেল) বাস্তবতার একটি কপি ব্যক্ত করে।	☐ Agree / সম্মত/ অনুমোদন করি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা …………………………………………
10. Scientists do not use creativity and imagination in developing scientific knowledge বৈজ্ঞানিক জ্ঞান বিকশিত করতে বিজ্ঞানীরা সৃজনশীলতা এবং কল্পনা ব্যবহার করেনা।	☐ Agree / সম্মত/ অনুমোদন করি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা …………………………………………
11. Scientists are open-minded without any biases বিজ্ঞানীগণখোলামনাএবংনিরপেক্ষহয়	☐ Agree / সম্মত/ অনুমোদনকরি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদনকরিনা
12. Science and technology are identical বিজ্ঞান এবং প্রযুক্তি অবিকল অনুরূপ	☐ Agree / সম্মত/ অনুমোদন করি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা …………………………………………

Figure 3.2 (Continued)

Statement (বিবৃতি/বক্তব্য)	**Opinion (মতামত)**
13. Scientific enterprise is an individual enterprise বৈজ্ঞানিক উদ্যোগ একটি স্বতন্ত্র উদ্যোগ	☐ Agree / সম্মত/ অনুমোদনকরি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা …………………………………………………
14. Society, politics, and culture do not affect the development of scientific knowledge সমাজ, রাজনীতি, এবং সংস্কৃতি, বৈজ্ঞানিক জ্ঞানের উন্নতি সাধনকে প্রভাবিত করেনা	☐ Agree / সম্মত/ অনুমোদনকরি ☐ Uncertain / অনিশ্চিত ☐ Disagree / অসম্মত/অনুমোদন করিনা ……………………………………………

Figure 3.2 (Continued)

3.1.1 Data Collection

The respondents were 110 science teachers (n = 110) in the division of Dhaka the capital city as well as the central region of Bangladesh. Ninety-two participants (83.6%) were male and eighteen participants (16.4%) were female. Fifty-one participants (46.4%) teach in a lower-secondary level and fifty nine participants (53.6%) teach in a higher-secondary level. The subjects they teach are mathematics (30%), physics (21.8%), chemistry (20.0%), biology (8.2%) and others (e.g. computer).

3.1.2 Data Analysis

The data obtained from the participants were both quantitative and qualitative. Consequently, two types of data analysis were conducted. First, the participants’ responses to the MOSQ were interpreted. That is the 'agree' ‘uncertain and disagree responses were respectively interpreted as uninformed uncertain and informed conceptions of NOS. Then, the participants' conceptions of NOS were analyzed by frequency counting as well as percentage calculating.

Second the participants written responses, views, or reasons put into categories. Throughout this qualitative data analysis, the data reduction, data display and conclusion drawing approaches were applied (Miles & Huberman, 1984). The written responses from each participant were used to support the interpretations of the three optional responses. For instance, one participant selected the "disagree" option for Item 2 "Scientific theories are less secured than scientific law", but he or she wrote in the opinion space that "scientific laws are more stable and unchanged and theories might change after further proving". So, the conclusion for this participant was "uninformed" rather than "informed".

3.2 Phase 2: Development of NOS Conceptions

The second phase aimed to explore the effect of the explicit-reflective NOS workshop on the development of NOS conceptions held by the participating science teachers. The respondents from the first phase were asked to volunteer to participate in this phase.

3.2.1 Data Collection

There were 16 volunteered science teachers (15 male and 1 female). Seven and nine participants teach in the lower-secondary and higher-secondary levels, respectively. There were 5, 3, 2, 3 and 3 participants who, respectively, teach mathematics, physics, chemistry, biology, and others (e.g. computer). These participants were asked to complete the MOSQ before and after participated in "An Explicit-Reflective NOS Workshop". The activities in the Explicit-Reflective NOS Workshop are as Figure 3.3

Activity	Name of activity	Related NOS aspects
1	Hierarchy Notion	• Hypotheses and theories • Theories and laws • NOS discussion and reflection
2	Tricky Tracks	• Observation vs. inferences • Scientists' creativity and imaginations • Tentativeness of science • NOS discussion and reflection
3	Young or Old	• Subjectivity in science • Influences of social and cultural contexts on science • NOS discussion and reflection
4	Mysterious Tube	• Scientific knowledge is a part of human imagination and creativity • Scientific model • Scientific hypotheses, theories and laws • NOS discussion and reflection
5	Cube	• Scientific knowledge is a part of human imagination and creativity • Scientific model • Scientific hypotheses, theories and laws • NOS discussion and reflection

Figure 3.3 The Explicit-Reflective NOS Workshop

The details of each activity in the explicit –reflective NOS workshop are illustrated below.

3.2.1 Workshop Activity 1: Hierarchy Notion

Related NOS Aspects:

Item 1 Hypotheses are developed to become theories only Item 2 Scientific theories are less secure than laws

Item 3 Scientific theories can be developed to become laws

Item 4 The scientific method is a fixed step-by-step process

Item 7 Scientific knowledge comes from experiments only

Procedures:

Use attached overheads to explicitly discuss with the participants about the wrong idea related to the hierarchical relationship among scientific hypothesis, theories and laws. Convey the correct idea and facts to them with reasoning.

These three entities are hierarchically presented in many textbooks and very simply explained that observations develop into hypothesis then hypothesis become theory and finally theory becomes law. It is also described that these hierarchically steps are depends on experiments, supportive evidence and proving. The more evidences can be accumulated, the higher the level of the hierarchy will be achieved. In another word, hypothesis will become theory only and theory will be developed to become law once a plenty of supportive empirical evidences are available to prove or to support it. Thus, it implies that laws are more secured than theories. Figure 3.4 show the notion hierarchical relationship of hypothesis, theories and laws,

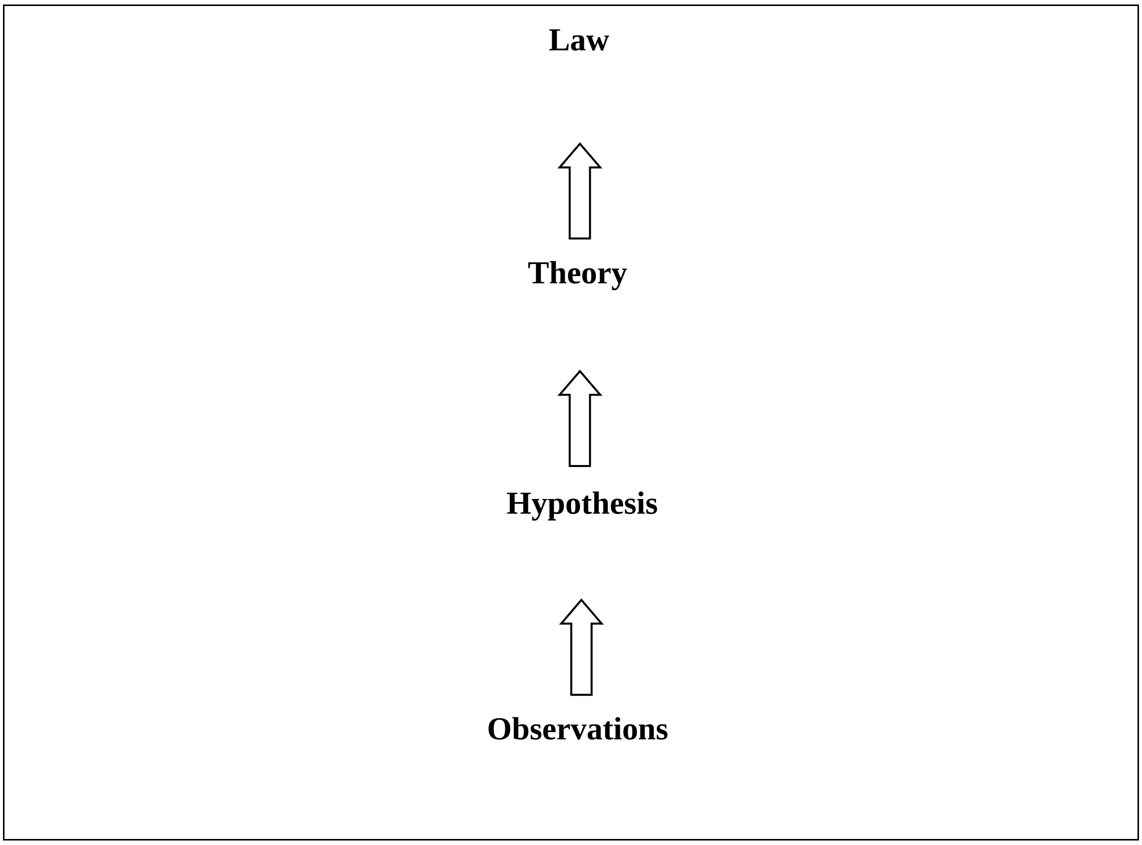

Figure 3.4 Notion hierarchical relationships of hypothesis, theories and laws

This hierarchical relationship as figure 3.4 is wrong for at least two reasons: a) Theory and law are different kind of knowledge; one cannot develop to another (Mc Comas, 1996). The theory is an explanation of any observable phenomena. Generally, the theory explains the reasons why things happen. On the other hand, the law describes the relationships among the observable objects or entities and generally, describes what happens. A hypothesis can serve as a pre-step for both theory and law. So, the hypothesis might be developed to theory or law or (even) none. Figure 3.5 describe the definitions of law and theory.

Scientific law

States, identifies or describes relationships among observable phenomena

Scientific theory

Inferred explanation for observable phenomena

Figure 3.5 Definitions of law and theory

From the history of science, it is known that "theories become law" is not a valid claim. For example, Boyles’ Law describe the relationship and the effect of one into another regarding the 'volume' and the 'pressure' of gas that was proposed by Rober Boyel in 1670. Kinetic Molecular theory that serves as the explanation of Boyles Law was introduced by Rudolph Clawsius and James Clerk Maxwell in 1850. Here the law came first and nearly after a century the related theory came. Geregor Mendel presented his law of inheritance in a paper in 1866, which is interpreted by Chromosomes theory in 1915 by Thomas Morgan and his coworkers (Mix, Farber and King, 1996). Again, the law came here first then related theory. So, the theory is developed to become law is an invalid claim.

Moreover, there are many laws that are being applied in modern life and the related theory of those laws cannot be introduced yet. For instance, Gravitational law was proposed by Isaac Newton in 1687 but no vital theory for this introduced yet. Newton himself tried to formulate a theory of gravitational law but was unsuccessful. So, still there are some laws that related theories are not introduced yet. Figure 3.6 presents the relationships of theories and law

Scientific Law	**Scientific Theory**
Boyle's Law	**Kinetic Molecular Theory**
Mendel's Laws of Inheritance	**Chromosome Theory**
Newton's law of universal Gravitation and Laws of Motion	**?**

Figure 3.6 the relationship of theories and laws

Figure 3.7 explains the appropriate relationship among scientific hypothesis, theories and laws. Hypothesis is introduced from the observation of natural phenomena. It can be the explanations of the respected phenomena or might the descriptions of the relationships among the observable entities itself. Primary observations are not theory, but it influences further observations, related hypothesis, laws and theories. The whole scientific knowledge is influenced by the socio-cultural context.

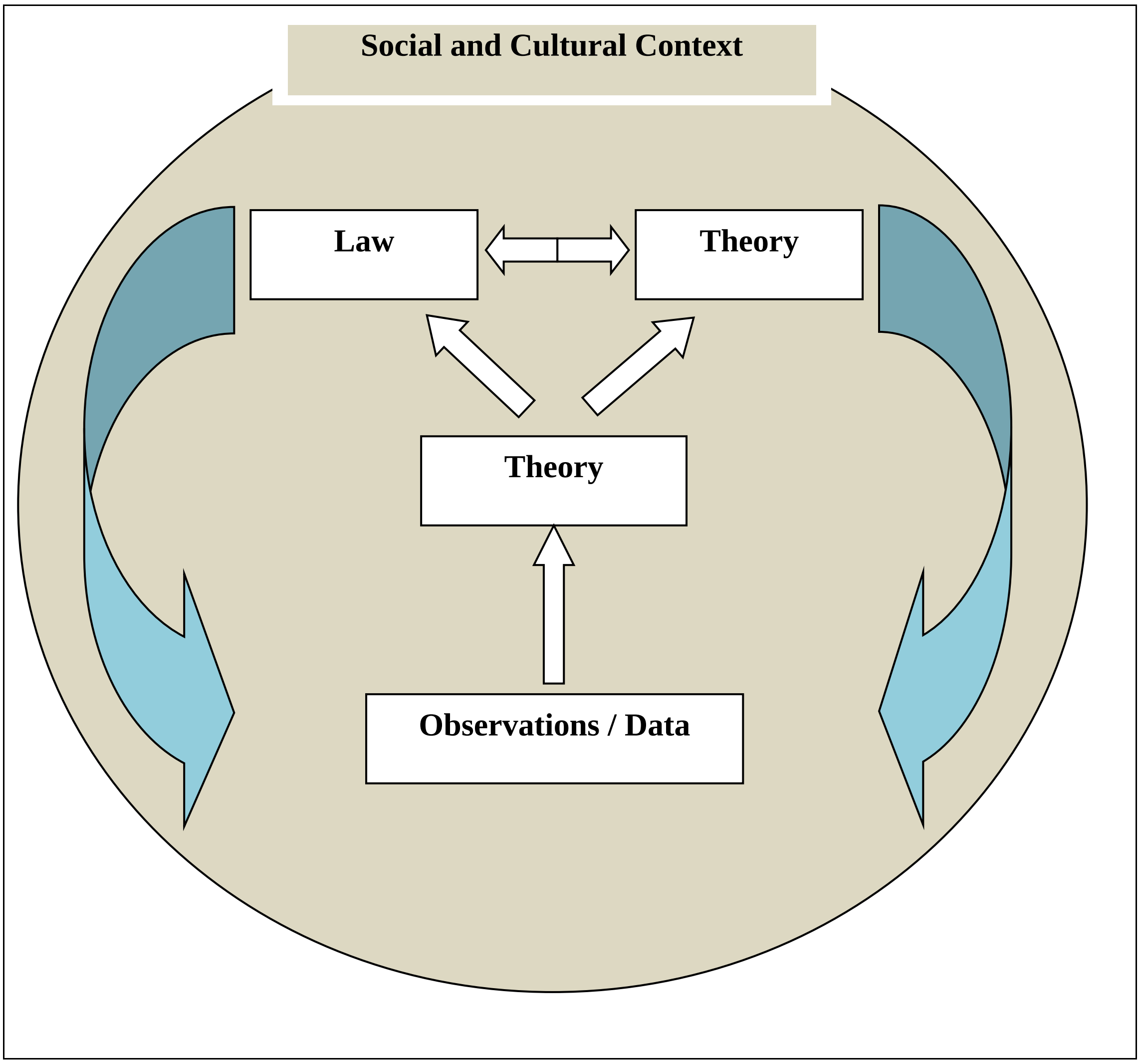

Figure 3.7 Alternative View of Relationship among Hypothesis, Law and Theory

Data are collected by depending on many investigations. A hypothesis or a set of hypothesis is formulated after testing and/or modifications. Overcoming this process, a hypothesis can be or cannot be developed to a theory or a law. There is no step-by-step of the scientific method. Influenced by the social and cultural context, it might take from several years to a century even. Thus, the scientific knowledge does not come from the experiments only. Once a law or theory is proposed, it opens the door for further investigations that might or might not introduce any new theory or law. This is the way that history of science is running.

3.2.3 Workshop Activity 2: Tricky Tracks

Related NOS Aspects:

Item 3 Scientific knowledge cannot be changed

Item 9 Scientists do not use creativity and imagination in developing scientific knowledge

Item 10 Scientists are open-minded without any biases

Procedures:

Show Figures 3.8 (a) on the overhead, ask the participants a) "what do you think as you see?", note down the answers of the participants one by one then ask again b) "can you see any birds or any animals"? Note down their reasoning for their justifications or logical guess. c) Explicitly discuss about the observations versus inferences with the participants.

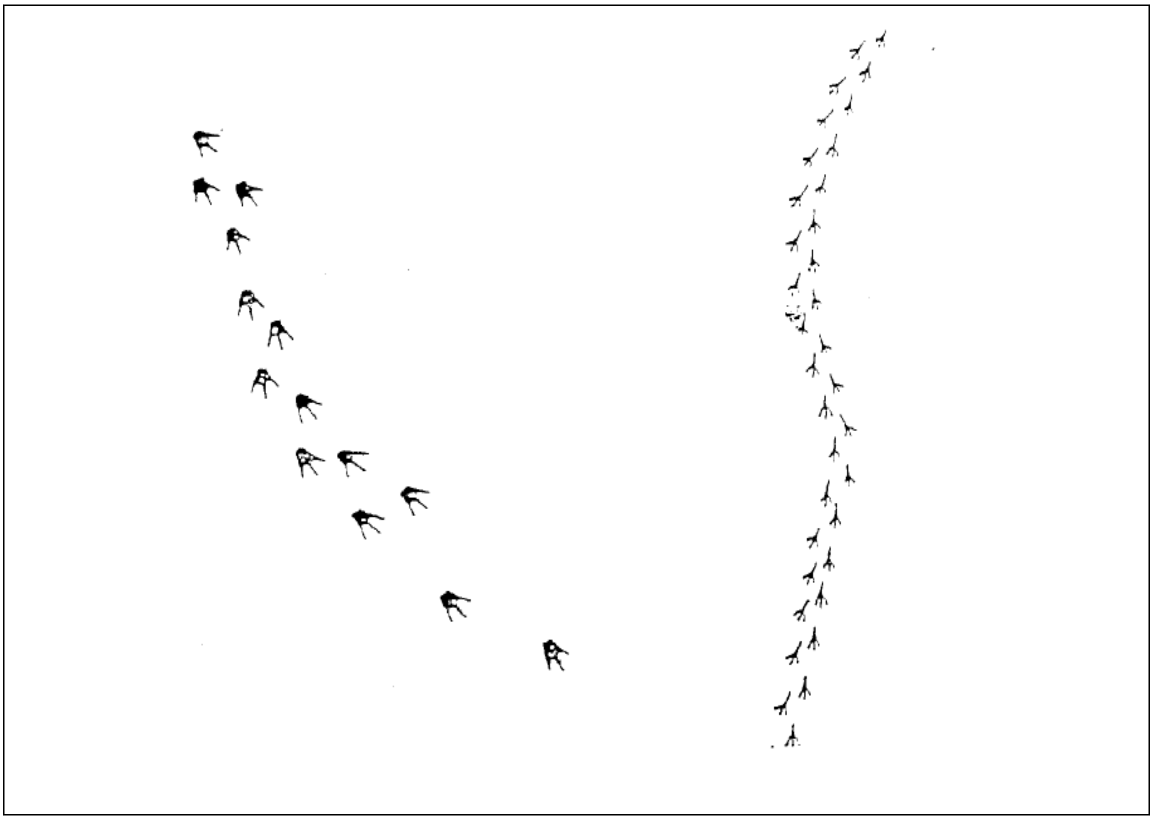

Figure 3.8 Tricky Tracks (a) [Source: Lederman, N., & Abd-El-Khalick, F. (1998)]

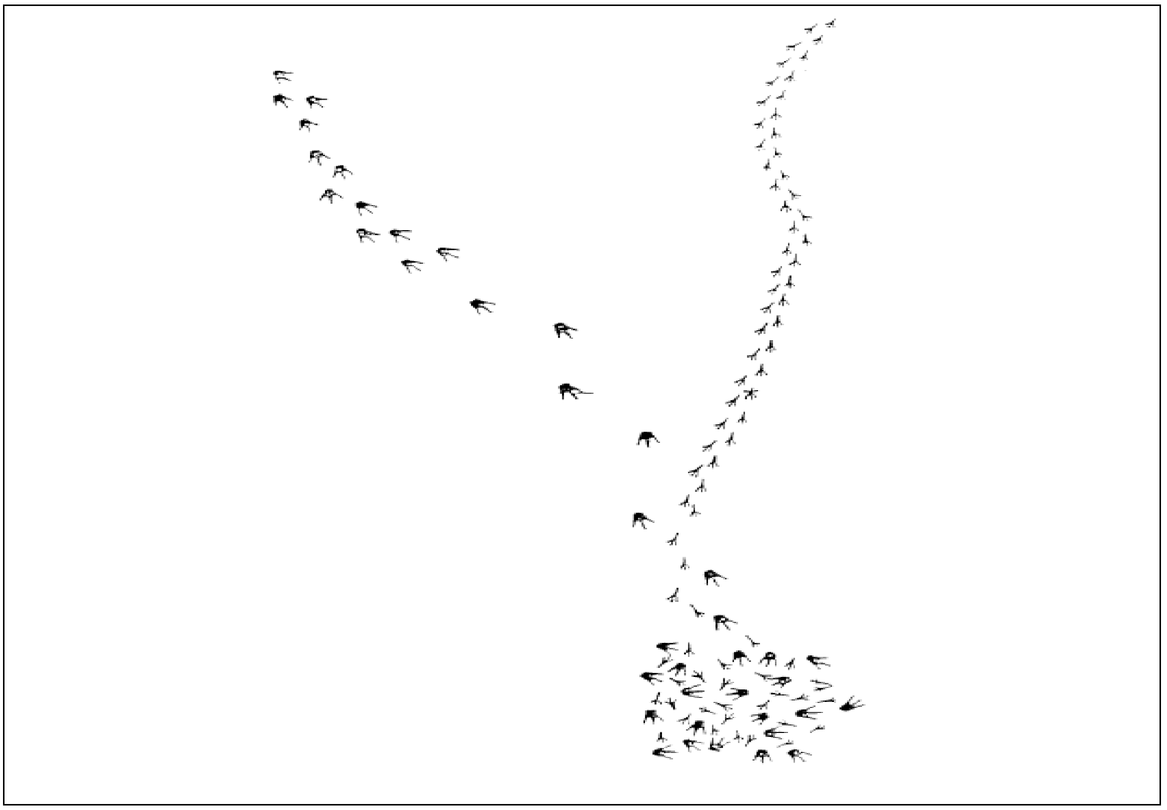

Figure 3.8 Tricky Tracks (b) [Source: Lederman, N., & Abd-El-Khalick, F. (1998)]

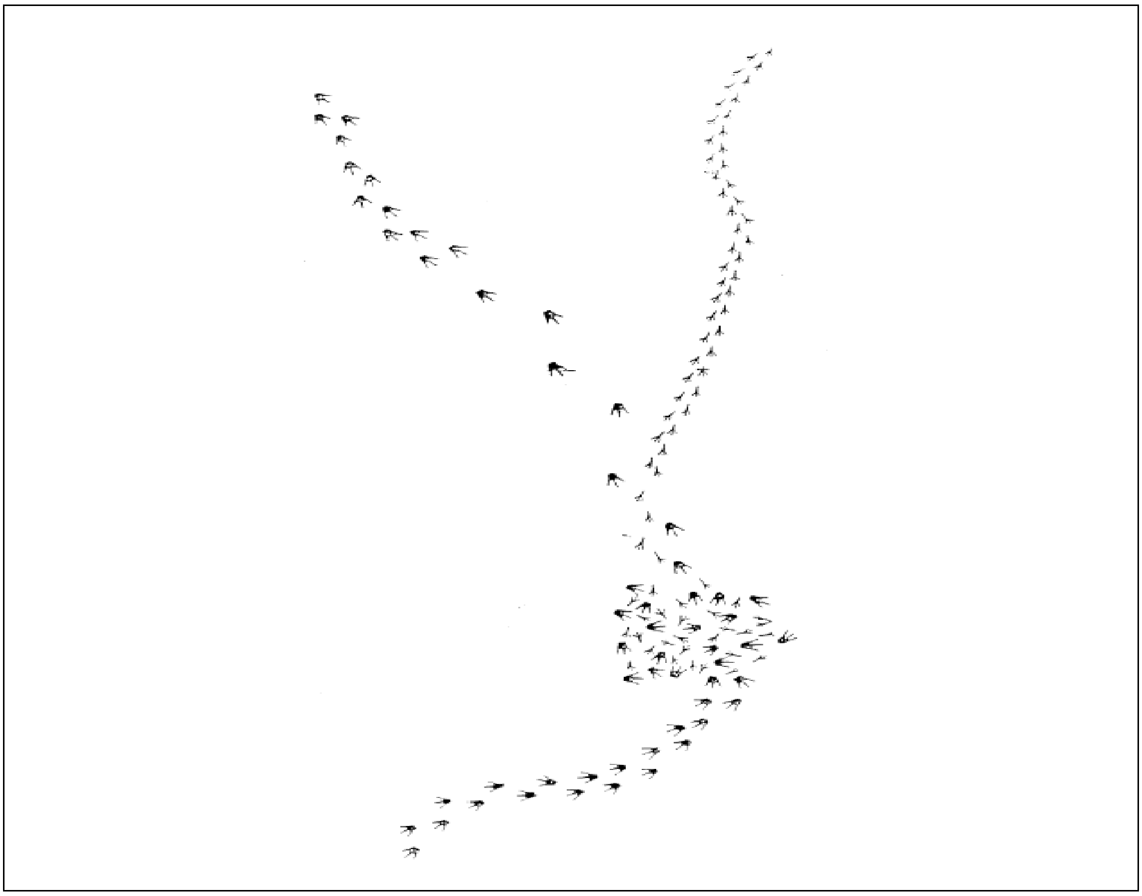

Figure 3.8 Tricky Tracks (c) [Source: Lederman, N., & Abd-El-Khalick, F. (1998)]

It is general that most of the participants express their ideas about the tricky tracks that it is the track of some kinds of birds or other animals' footsteps. Once second question was asked “can you see any bird or animal”, the answer is obviously “No”. What are seen on the paper as some black color shapes. For the Figure 3.8(b), it seems that this animals are gone such as birds are flying away. Actually, observations are justified by the observers’ prior knowledge. It is inferences.

When Figure 3.8(b) is presented and closely observed in more details and in more logically presented, the participants uses their imagination or creativity to explain their inferences with more arguments such as the animal might heading going towards some destination for foods or water and somehow they died over there and eaten by their predators. By observing further more Figure 3.8(c), both types of animals might heading towards same source for same purpose but the weaker is eaten or killed by the stronger and finally the winner group is leaving the spot. These all are inferences and might be possible. And it is possible to come up with different inferences with supporting logical evidences from the same observation.

Scientists might observe the natural phenomena, collect data, make inference, based collected data, and by all possible consistent data they try to answers their questions. This process might influenced by their creativity and imagination. Their prior knowledge might help them to infer the new situations as it happened to the participants. After that, they might do more experiments and test to gather more sensible supporting data to prove their findings.

So, scientific knowledge is changeable and it depends on socio-cultural context. One who comes up with some phenomena with proven supports and evidence then it might be acceptable in some extent. Scientists are creative and imaginative in their investigations. As human beings, they are not above the influence of the environments, so they might not be always opened minded**.** Even though scientific knowledge emphatically evidence based, it is socio-culturally embedded. Scientists are the part of that and might be biased too.

3.2.4 Workshop Activity 3: Young or Old

Related NOS Aspects:

Item 10 Scientists are open-minded without any biases

Item 14 Society, politics, and culture do not affect the development of scientific knowledge

Procedures:

Use Figure 3.9 on the overhead, ask the participants a) "what do you think as you see?" note down the answers of the participants one by one. Then ask again b) "can you explain your thinking?" Note down their reasoning for their justifications or logical guess. Explicitly discuss with the participants about the scientists' work, and the influences of society, politics, and culture on scientific knowledge.

Figure 3.9 Young or old [Source: Lederman, N., & Abd-El-Khalick, F. (1998)]

Some participants came up with confident conclusion that the drawing is of an old lady. Some others see it as a young lady looking at the other side. Few argued that this drawing is showing a bird or an animal eating something. From the explanations, the participants able to argue with their own logic about the face, nose, eye, check, hair, neck of young or old lady. The supporter of bird or other animal even tried to establish their argument by providing logical sign of the drawing they observed. All of their arguments were based on their observations, and inferences. They have used their background knowledge with the observed drawing and fond out different picture based on their scientific knowledge, and experience which are accumulated from culture and society as well.

This is the way that scientists actually work; they observe the natural phenomena and try to find out the answer of their questions. From the similar observations, different scientists might come up with different findings. All of them might have their own evidences to support their arguments. They might use their background knowledge, skills and experiences. Ones' arguments might or might not acceptable by others, because of their lack of open mind ness and social, cultural, and politically embedded scientific knowledge.

3.2.5 Workshop Activity 4: Mysterious Tube

Related NOS Aspects:

Item 9 A scientific models (e.g., the atomic model) express a copy of reality

Item 10 Scientists do not use creativity and imagination in developing scientific knowledge

Procedures:

Present handmade (from rolled tissue holder) model of "Black Box or Mysterious Tube" and use Figure 3.7(a) and 3.7(b) on the overhead, and ask the participants a) "What do you think as you see?" note down the answers of the participants one by one. Then ask again b) "Can you explain your thinking?" Note down their reasoning for their justifications or logical guess. Explicitly discuss with the participants about the scientists' work, and scientific model.

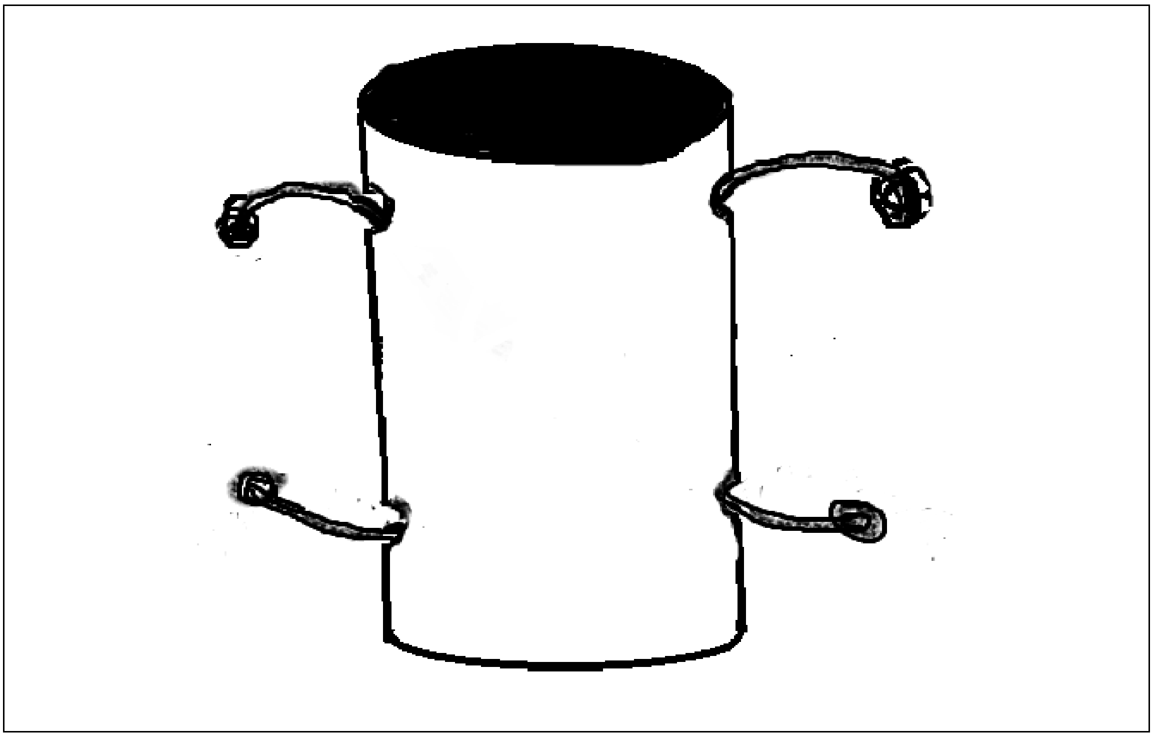

Figure 3.10 Myterioius tube (a) outside

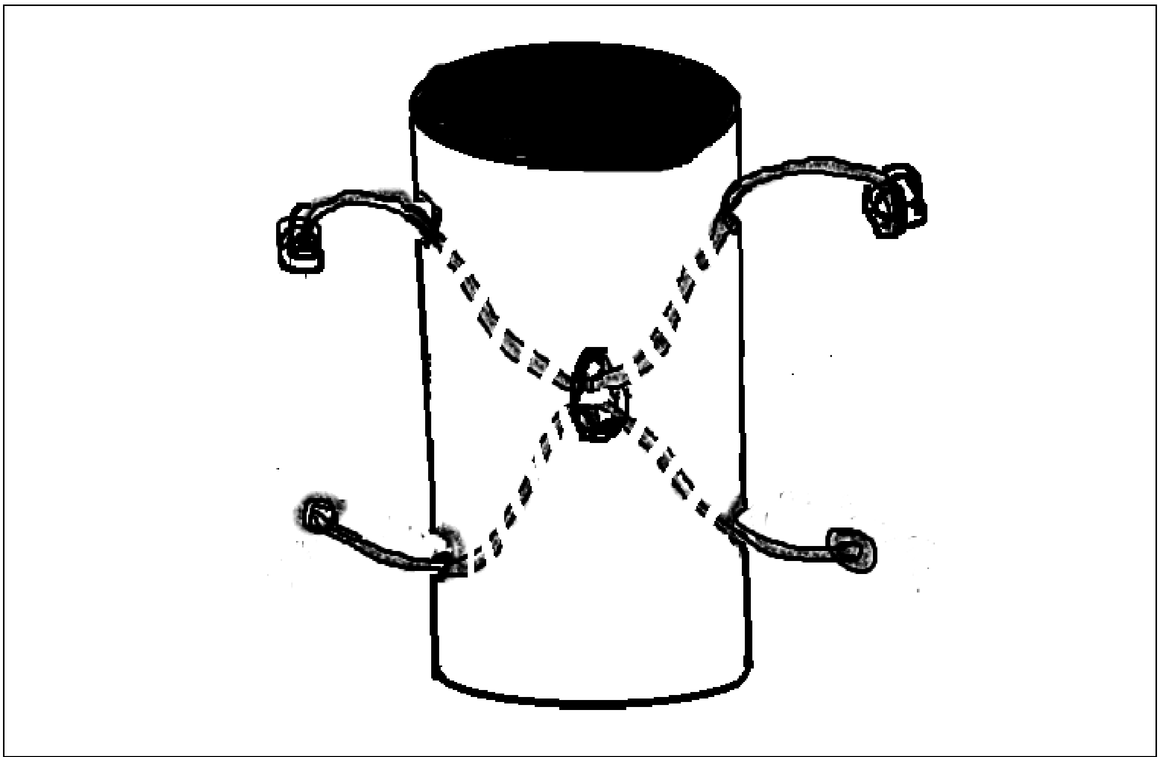

Figure 3.10 Myterioius tube (b) inside

Participants inferred as they see the mysterious tube or black box. Some to them expressed their idea such as, the pieces of two ropes are horizontally same piece and vertically separated two pieces of rope or it's two pieces are vertically separated, or the ropes are attached together crosswise inside. The real picture of inside is unknown and the participants are trying to imagine and pull the one side of the rope and observe what happens to the other side of the rope. As the opposite sided rope is responding or becoming shorter, so they concluding that they are attached together inside the tube.

Scientists' work is very much similar to this. In order to come up with or discover a new phenomenon, scientists observer all passible and available points, Collect data, make an inference, propose a hypothesis, to go further according to the hypothesis, do experiments and tastings, come up with rough conclusion and then create a scientific model using their imaginations to explain their investigations and phenomena, try to make sensible logical answers with evidence of the unknown phenomena.

3.2.6 Workshop Activity 5: Cube

Related NOS Aspects:

Item 10 Scientists do not use creativity and imagination in developing scientific knowledge

Procedures:

Present handmade (from folded paper Cube) model of "Black Box or Mysterious Cube" and use Figure 3.11 (a) on the overhead, and ask the participants a) "What do you think about the unseen number in the cube ?", note down the answers of the participants one by one., Then ask again b) "Can you explain your thinking?" Note down their reasoning for their justifications or logical guess. Explicitly discuss with the participants about the scientists' work by presenting Figure 3.11 (b) on the overhead,

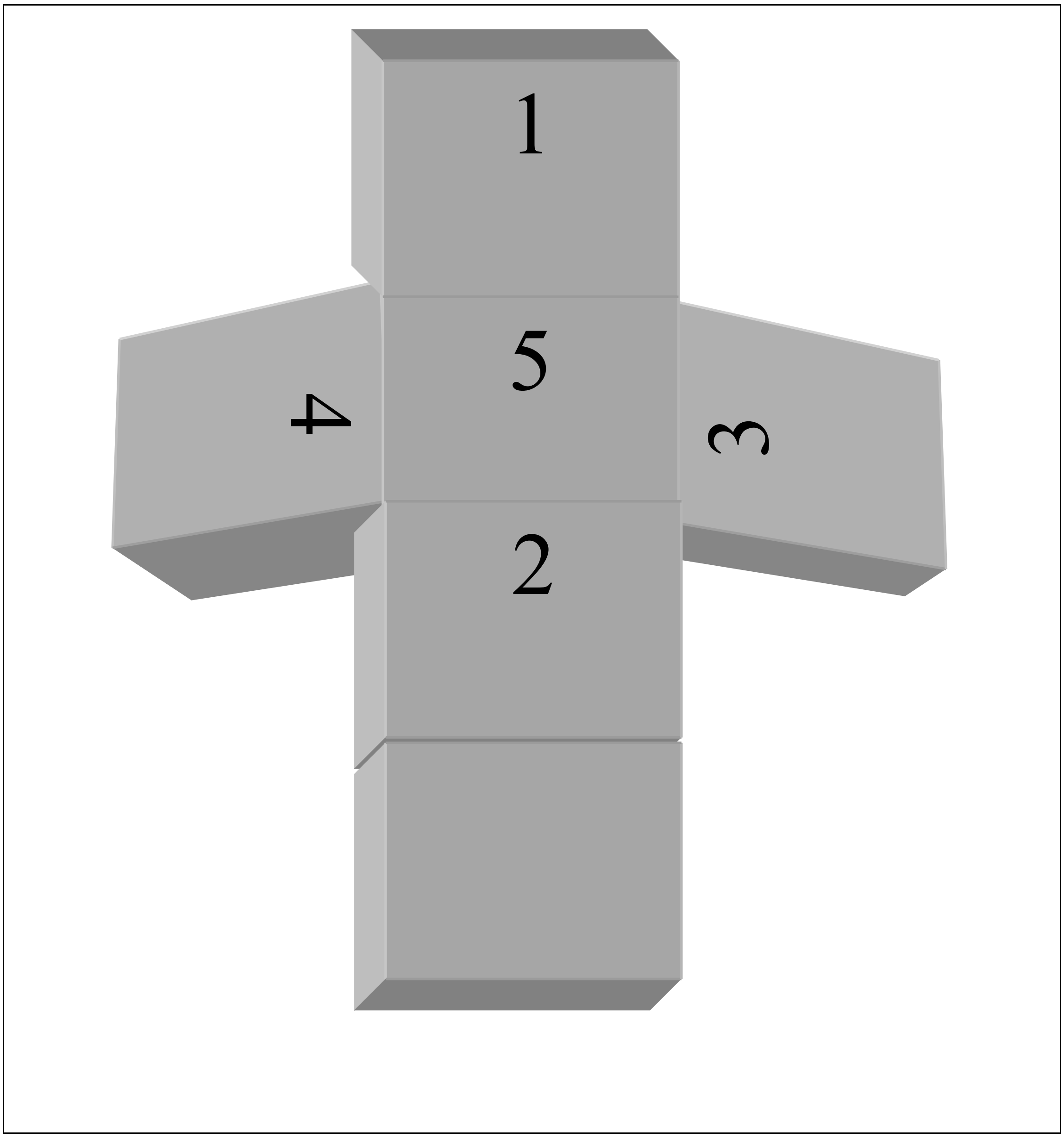

Figure 3.11 Myterioius Cube (a)

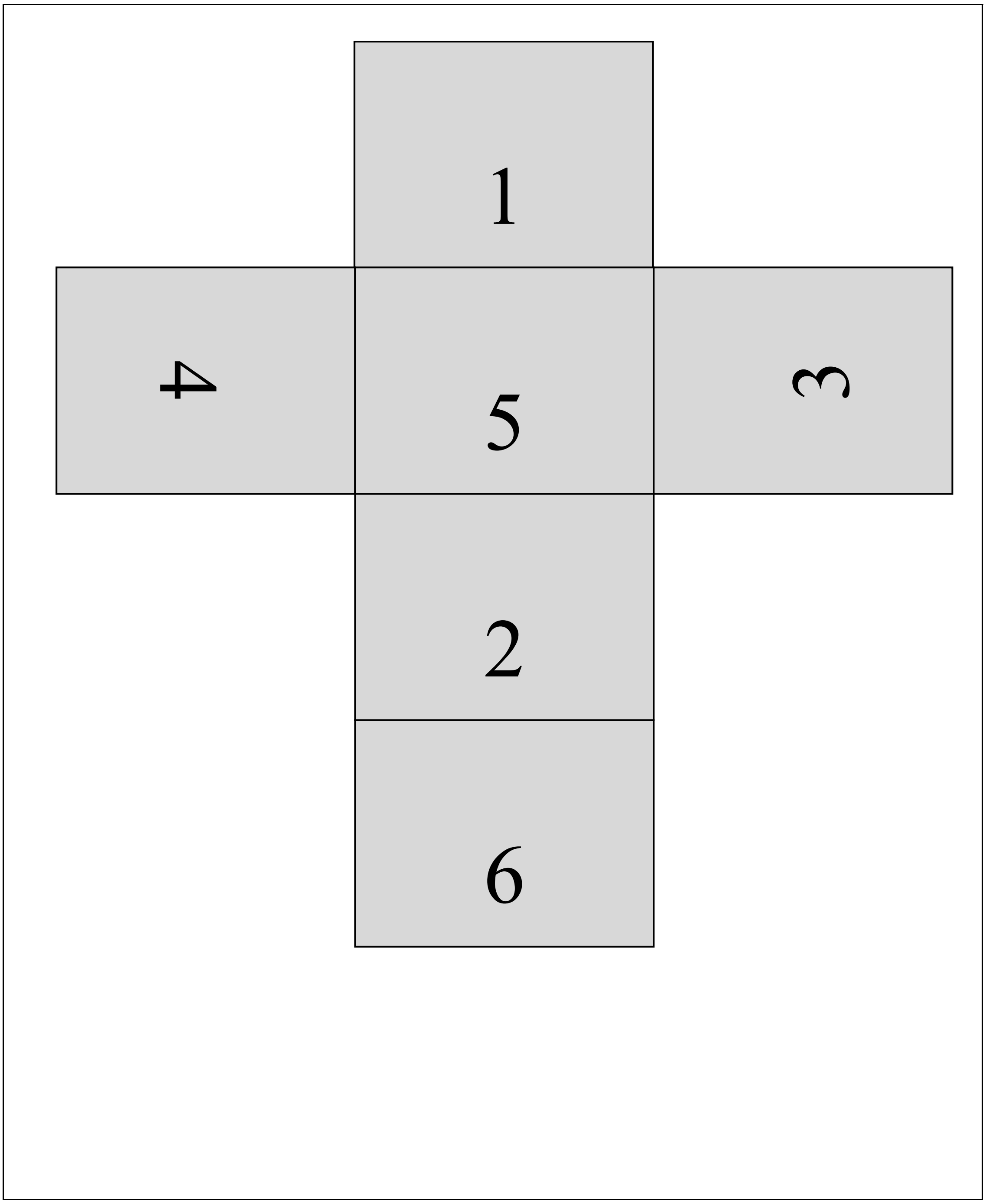

Figure 3.11 Myterioius Cube (b)

By observing the cube, all of the participants inferred that, the unseen number might be ‘6’. Five sides of the cube is filled with the five numbers 1, 2, 3, 4, and 5. There are six sides in a cube. If we see the pattern, then it easily inferred that the next number should be ‘6’. Moreover the five sides of the cube is known already, so the unknown side is obvious to be the next number of the pattern and that is number '6'.

Similarly Scientists works can be referred as this mysterious cube. They observe the natural phenomena, collect the data, look for the pattern, infer the unknown data, and support the evidence for their proposed answers. Propose a hypothesis, do more experiments, testing and collect more data and finally conclude scientifically from their findings and results. Imaginations, creativity and their background knowledge lead them to their observations, investigations, scientific inquiry, hypothesis constructing, and scientific discovering process. These are the fundamental systematic process that a scientist comes over to reveal the unknown natural phenomena.

So, the 'black box' or 'mysterious cube' activity refers that scientific knowledge is influenced by human inference, imaginations and creativity. Scientific knowledge depends on empirical, and inherited from observation, experiments and evidence. Scientific models are constructed and used to describe and explain natural phenomena.

3.3.3 Data analysis

The participants' responses about NOS and NOS activities were coded and categorized by using a constant comparative method (Glaser & Strauss, 1967). First, each unit of meaning of responses was read and assigned a code. Then, codes were compared for their similarities and differences in term of meanings. The codes with similar meaning were grouped together and create a category for them. The codes with different meaning were put apart and wait for other suitable categories. This process was conducted continuously until all codes were assigned to appropriated categories. At final, the researcher interpreted the results from the categories emerged.

CHAPTER IV
RESULTS

The findings came out from this study are presented in this chapter, in two main phases; (a) The science teachers' conceptions of NOS, and (b) the science teachers' development of NOS conceptions after took part in the workshop.

4.1 Phase 1: Science Teachers' Conceptions of NOS

The overall findings about the participants' conceptions of NOS are presented as Table 4.1

Table 4.1 Science teachers' conceptions of NOS

Item	**Response**		
	Agree (Uninformed)	Uncertain	Disagree (Informed)
Item 1: Hypotheses are developed to become theory only	64 (58.2%)	19 (17.3%)	27 (24.5%)
Item 2: Scientific theories are less secured than scientific law	79 (71.8%)	19 (17.3%)	12 (10.9%)
Item 3: Scientific theories can be developed to scientific law	75 (68.2%)	21 (19.1%)	14 (12.7%)
Item 4: Scientific knowledge can't be changed	36 (32.7%)	16 (14.5%)	58 (52.7%)

Table 4.1 Science teachers' conceptions of NOS (Cont.)

Item	Response		
	Agree (Uninformed)	Uncertain	Disagree (informed)
Item 5: Scientific method is a specific thorough (step-by step) process	79 (71.8%)	20 (18.2%)	11 (10.0%)
Item 6: Science and scientific method can answer all questions	39 (35.5%)	25 (22.7%)	46 (41.8%)
Item 7: Scientific knowledge comes from experiments only	70 (63.6%)	19 (17.3%)	21 (19.1%)
Item 8: Accumulation of evidence makes scientific knowledge more stable	86 (78.2%)	11 (10.0%)	13 (11.8%)
Item 9: A scientific model (e.g. Atomic model) expresses the copy of reality	59 (53.6%)	38 (34.5%)	13 (11.8%)
Item10: Scientists don't use creativity and imagination to develop Scientific knowledge	54 (49.1%)	20 (18.2%)	36 (32.7%)
Item11: Scientists are open minded and neutral	69 (62.7%)	17 (15.5%)	24 (21.8%)
Item12: Science and technology are exactly similar	46 (41.8%)	24 (21.8%)	40 (36.4%)
Item13: Scientific endeavor is an individual endeavor	74 (67.3%)	22 (20.0%)	14 (12.7%)
Item14: Society, politics and culture don't influence on scientific development	45 (40.9%)	7 (6.4%)	58 (52.7%)

From Table 4.1, in Item 1 only about one-fourth of the participants held informed conceptions about the relationship between hypotheses and theories. More than half of them had uninformed conception of NOS that hypotheses are developed to become theories only and a number of them (17%) are not sure about the relationship.

According to Item 2, nearly three quarters of the participants indicated uninformed conception about the stability and vulnerability of scientific theories and scientific laws. They believed in a hierarchical structure between theories and laws, that is, scientific theories are less secured than laws and on contrary one-fifth of them were not sure about the hierarchical structure between theories and laws, in addition, only one-tenth of them had correct knowledge.

In Item 3, in similar to Item 2, three-forth of the participants reflected the uninformed conceptions about the hierarchical structure between theories and laws. They believed that scientific laws are superior than theories so that scientific theories must be developed to become laws. Only one-tenth of the participants believed that, there is no superiority between theories and laws where, approximately one fifth of them are uncertain about the fact.

In Item 4, more than a half of the participants showed informed conception about the tentativeness of scientific knowledge. They agreed that scientific knowledge can be changed. But at the same time, one third of them indicated uninformed conception and a numbers of them are uncertain about the tentativeness of scientific knowledge.

Surprisingly, only one-tenth of the participants held informed conceptions about scientific method in Item 5. Almost all of them had uninformed conception of NOS, that is, scientific method is a specific step-by-step process. In addition to that, one-fifth of the participants were uncertain about process of scientific method.

Even though nearly a half of the participants indicated informed conceptions in Item 6 which shows that science and scientific method cannot answer all questions, but approximately two fifth of them showed uninformed conceptions as well as more than one-fifth of them were uncertain about it.

In Item 7, more than a half of the participants held uninformed conception of NOS that scientific knowledge comes from experiments only. In this case, only less than one-fifth of the participants held informed conceptions that scientific knowledge can be derived from other methods.

As of Item 8, more than three-forth of the participants possessed uninformed conception of NOS that "the accumulation of evidence makes scientific knowledge more stable". A small number of the participants (11.8%) held informed conception about this. In addition to that, one tenth of them are not sure whether Accumulation of evidence makes scientific knowledge more stable or not.

The highest percentage of the participants (38%) who being uncertain was appeared in Item 9 “A scientific model (e.g. Atomic model) expresses the copy of reality”. Fifty-nine percent of them held uninformed conception, while a few numbers of participants (11.8%) were aware that scientific models do not express the copy of realities.

Even though one-third of the participants agreed with Item 10, nearly a half of them held uninformed conception of NOS that scientists do not use creativity and imagination to develop scientific knowledge. Moreover, nearly one-fifth of them are not quite sure about scientists' work.

Similarly to Item 10, more than three-fifth of the participants held uniformed conception of NOS in Item 11, that is, scientists are open minded and neutral. Only one-fifth of them could come up with informed conception about the scientist’s personal ideology, on the other hand, more than fifteen percent of the participants are not sure about scientists' openness.

In Item 12, the participants who held uninformed (41.8%) and informed (36.4%) conception of NOS regarding science and technology are almost similar. More than one-fifth of the participants were uncertain whether, science and technology are exactly similar or not.

Response of Item 13 indicated that, sixty seven percent of the participants held uninformed conceptions where only twelve percent of them had informed conception of NOS that scientific endeavor is not an individual endeavor. In addition to that, one-fifth of the participants are not sure about the fact.

Even though more than a half of the participants held informed conception about the relationship between science, society, politics and culture in Item 14, two-fifth of them held uninformed conception, and a few numbers of the participants (6%) were uncertain about the relationship.

In the overall, there are two items (i.e. Items 4 and 14) which the participants had informed conceptions of NOS with similar number (52.7%). Item 4 deals with the tentativeness of scientific knowledge while Item 14 deals with the relationship between science, society, politics and culture. There are two items (i.e. Items 3 and 13) in which a few participants (12.7%) had informed conceptions of

NOS. Item 3 addresses the hierarchically superiority of scientific laws on scientific theories and Item 13 stands for scientific endeavors. The uninformed responses of these two items are also very similar.

In the other two items (i.e. Items 8 and 9), in similar to Items 3 and 13, there is a small number of participants (11.8%) who had informed conceptions. In Item 8, most of the participants believed that accumulation of evidence makes scientific knowledge more stable and in Item 9, around a half of the participants held uninformed conception that a scientific model express the copy of reality.

From Table 1, in Items 2 and 5, the same number of participants (71.8%) held uninformed conceptions which indicated that the participants believed that scientific theories are less secured than scientific law and the scientific method is a specific thorough (step-by-step) process. These are the second highest uninformed conceptions of NOS. The most uncertain responses found in Item 9, where thirty five percent of the participants are not sure about A scientific model express the copy of reality or not. On the other hand, the least uncertain participants (6.4%) indicated in Item 14, that the participants are doubt about the influence of society , politics and culture on scientific development or not.

4.2 Phase 2: Science Teachers' Development of NOS Conceptions After the Explicit-Reflective NOS Workshop.

The overall findings about the participants' conceptions of NOS are presented as Table 4.2

Table 4.2 Science teachers' development of conceptions of NOS after participating the workshop

Item	Pre-response			Post-response		
	Agree	Uncertain	Disagree	Agree	Uncertain	Disagree
Item 1: Hypotheses are developed to become theories only	8 (50%)	3 (18.8%)	5 (31.3%)	0 (0%)	0 (0%)	16 (100%)
Item 2: Scientific theories are less secured than scientific law	12 (75%)	4 (25%)	0 (0%)	1 (6%)	0 (0%)	15 (94%)
Item 3: Scientific theories can be developed to scientific law	13 (81.5%)	1 (6%)	2 (12.5%)	2 (12.5%)	0 (0%)	14 (87.5%)
Item 4: Scientific knowledge can't be changed	4 (25%)	2 (12.5%)	10 (62.5%)	0 (0%)	0 (0%)	16 (100%)
Item 5: Scientific method is a specific thorough (step-by step) process	12 (75%)	3 (18.8%)	1 (6.3%)	0 (0%)	0 (0%)	16 (100%)
Item 6: Science and scientific method can answer all questions	2 (12.5%)	3 (18.3%)	11 (68.8%)	0 (0%)	0 (0%)	16 (100%)
Item 7: Scientific knowledge comes from experiments only	11 (68.8%)	2 (12.5%)	3 (18.8%)	4 (25%)	0 (0%)	12 (75%)
Item 8: Accumulation of evidence makes scientific knowledge more stable	13 (81.3%)	2 (12.5%)	1 (6.3%)	5 (31.3%)	1 (6.3%)	10 (62.5%)
Item 9: A scientific model (e.g. Atomic model) expresses the copy of reality	7 (43.8%)	7 (43.8%)	2 (12.5%)	2 (12.5%)	0 (0%)	14 (87.5%)
Item10: Scientists don't use creativity and imagination to develop Scientific knowledge	6 (37.5%)	3 (18.8%)	7 (43.8%)	3 (18.8%)	0 (0%)	13 (81.3%)
Item11: Scientists are open minded and neutral	11 (68.8%)	1 (6.3%)	4 (25%)	2 (12.5%)	0 (0%)	14 (87.5%)
Item12: Science and technology are exactly similar	7 (43.8%)	2 (12.5%)	7 (43.8%)	0 (0%)	0 (0%)	16 (100%)
Item13: Scientific endeavor is an individual endeavor	13 (81.3%)	3 (18.8%)	0 (0%)	1 (6%)	0 (0%)	15 (94%)
Item14: Society, politics and culture don't influence on scientific development	4 (25%)	0 (0%)	12 (75%)	2 (12.5%)	0 (0%)	14 (87.5%)

From Table 4.2, the overall result showed that the NOS workshop helped the participants developed more informed understanding of NOS.

In Item 1, before the workshop, only five participants had informed conception of NOS about the relationship between scientific hypotheses and theories. After the workshop, all participants could come up with the informed conception of NOS. After the workshop program, informed conceptions have increased from 31.3% to 100%. In addition to that, uninformed conceptions has decreased from 50 % to 0% as well as uncertain has shifted to 18.8% to 0%.

Even though none of participants held informed conception of NOS about the relationship between scientific theories and laws (Item 2) before the workshop, almost all participants (94%) developed more informed conception of NOS. Moreover, uninformed conception responses (75%) before the workshop has been decreased to only 6% after the workshop as uncertainty decreased from 25% to 0% after the workshop as well.

According to Item 3, at the beginning, two participants showed uninformed perception of NOS regarding the hierarchical relationship between scientific theories and laws. By the end of the workshop fourteen participants indicated informed conceptions that scientific theories cannot be developed to scientific laws. Furthermore, uninformed conceptions reduced from 81.5% to 12.5% after the workshop.

About the tentativeness of scientific knowledge in Item 4, the number of participants who expressed informed conception that scientific knowledge is changeable was increased from 10 to 16. Additionally, indication of uninformed and uncertain conceptions became 0% after the workshop program.

Tremendous improvement found In Item 5, only one participant held informed conception about scientific method prior to the workshop. However, all of them could come up with informed conception after the workshop that scientific method is not a specific step-by-step process. Besides this, 75% and 18.8% of the responses were uninformed and uncertain respectively before the workshop where the picture completely changed and the number of uninformed and uncertain became zero after the great workshop. All of the participants are agree that scientific method is not a specific thorough (step-by-step).

Prior the workshop, there were 11 participants who held informed conception that science and scientific method cannot answer all questions. After the workshop, the number of participants who had informed conception was increased to 16. Moreover, no more uninformed or uncertain conceptions were existing after the workshop program means science and scientific method can't answer all questions.

Only three participants possessed informed conception about a variety of ways to come up with scientific knowledge before the workshop; 11 participants stuck with experiment as only one way to come up with scientific knowledge. However, after the workshop, there were 12 participants who could develop informed conception about it. Even though, it's very difficult to change ones belief but with the effective workshop, uninformed conception about the Item 7 reduced from 68.8% to 25% and uncertainty has changed from 12.5% to 0% after the workshop, which implies that, till now there are some participants who believe that scientific knowledge comes from experiments only.

In Item 8, only one participant asserted informed conception of NOS about the accumulation of evidence enhancing the stability of scientific knowledge before the workshop. After the workshop, there were 10 participants who reached informed conception of NOS regarding this aspect. Similar to the previous Item, the participants were very much rigid to the content of this Item; hence it's not easy for them to change their previous conceptions. Despite of that, the uninformed conceptions reduced from 81.3% to 31.3% means half of them have changed and uncertainty also reduced after the workshop.

Prior the workshop, there were only two participants, who possessed informed conception that a scientific model is not a copy of reality. Seven participants had uninformed conception about that. However, after the workshop, there were 14 participants who expressed informed conception about a scientific model. In addition to that, seven people were uninformed and seven people were uncertain about the fact, but immediately after the workshop, the numbers changed and became two and zero respectively which refers that no one is unclear about the statement but till now two persons believed that a scientific model expresses the copy of reality.

Even though seven and six participants respectively held informed and uninformed conception in Item 10 before the workshop, 13 participants came up with informed conceptions of NOS that scientists do use creativity and imagination to develop scientific knowledge. Furthermore, the percentage of uninformed conceptions reduced from 37.5% to 18.8% and uncertain concept has lessen from 18.8% to 0% after the workshop.

In Item 11, only four participants indicated informed conceptions about the scientist's personal ideology before the workshop. Fourteen participants came up with informed conception about scientists and their subjectivity after the workshop. Additionally, more than half of the uninformed participants has changed their conceptions to informed that scientists are not open minded and neutral, as well as no uncertain conceptions remained after the workshop program.

According to Item 12, the numbers of participants with informed and uninformed conception about science and technology before the workshop are similar (n = 7). After the workshop, the number of participants with uninformed conception was decreased to zero and the number of participants with informed conception was risen up to 16. Deliberately, all participants held informed conception of NOS that science and technology are not exactly similar.

Very big change and improvement occurred in Item 13, where none of the participant held informed conception before the workshop in Item 13. Subsequently, almost all of them (n=15) came up with informed conception that scientific endeavor is not an individual endeavor after the workshop. Furthermore, 81.3% of participants were retaining uninformed conception about the fact which reduced to 6% and 18.8% uncertain participants shifted their conceptions in to informed conceptions after the workshop program.

Many participants (n = 12) had informed conception about the relationship between science, society, politics, and culture at the beginning. The workshop increased the number of participants to 14 at the end of the workshop. From observation during the workshop, the participants were enthusiastic and eagerly to learn in the workshop. Before the workshop, they prepared their materials ready to learn such as paper and pencils.

At the introduction of the workshop, they started to pay full attention and concentration to the presentation. After that, they became more curious as well as cooperatively participate in hands-on tasks. The participants were excited about what would be going to happen from particular activities. When their prediction or explanation concerning some pictures, figures and models, which were presented to them, were not in line with informed conceptions of NOS, they expressed their curiosity. With the age 30 to 40 years old, they were readiness to accept the informed conceptions of NOS. That is, they changed their uninformed to informed conceptions of NOS. At the middle of the workshop, there were two to three participants asked the questions related to NOS. After that, they clarified that they could figure out about their misconceptions of NOS and ended up with correct ones. Some of the participants look the model in their hands with curious eyes and expressed their thinking and opinions. The participants tried to communicate their ideas and opinions to the other participants. It is a constructive learning environment. The workshop ended up with the participants' recommendations about the workshop and completion of the post-questionnaire.

In addition, from interview with the participants, I found that they were very interested about the effective and successful workshop as one participant said:

> I've attended a number of seminars and short training program while doing teaching job for last seven years, I've discovered this workshop program is the really better ever I can say as I'm able to came up with many new things related to scientific fact within very short time. The workshop is very useful and interesting so far. (ST006, DBSTC interview)

Another participant express as:

> It is the third time for me joining this kind of program, Actually I like

> these as we can learn new things. Today's program is fantastic as it introduced old things (the Nature of Science's) in a new way. I feeling happy and lucky as I could participate here today (ST011, DBSTC interview)

While answering the questions about feeling regarding the workshop, some of the participants pointed out and suggested to conduct such kind of the workshop in a larger size. They indicated their concern about the other science teachers and want other science teachers to learn and understand about NOS.

> one the interviewee is expressing his thinking like: if we all secondary and higher secondary science teachers could join these kinds of workshop twice or at least ones a year so that, science teachers would be able to get rid of from their misconceptions as well as they could updated themselves with new innovations and discoveries. (ST003, DBSTC interview)

Some of the participants attributed the responsibility of misconception about NOS to the traditional methods of teaching and learning science (e.g. chalk-and-talk) in the classroom practice, though they themselves follow such tradition one.

> Actually students learn from their teacher and mostly in the class room, and so did we, we are conveying today to our students as we have inherited form our teachers during our learning periods in the old styled classrooms. (ST011,DBSTC interview) (ST003, DBSTC interview) .

The participants replied to the question of how to improve understanding of NOS by the workshop that science teachers must emphasize more interactive teaching and learning methods than traditional one.

> As Mr.A said: you can easily recognize the changes and total improvement of my conceptions regarding NOS form the workshop as you compare my pre and post questionnaire paper. I really like the modern interactive method than the traditional one and it (interactive) always works better. (ST011, DBSTC interview)

According to two interviewee, among all of the activities (Tricky Tracks, Young or Old, and Black Box), Black Box activity was more dynamic and explanative regarding NOS as it shows that science is not absolute, it can be changed depending on empirical evidence. In addition, scientists are subjective in developing scientific knowledge. Moreover, they added that one activity can clarify more than one aspects of NOS.

> Tricky tracks and Young or Old will tell you about many men many minds and the activity that you showed by making model of a black box is clear for someone to understand science which tell you that you must collect data from your observation to reach a certain conclusion and different people can have similar but different outcomes based on their knowledge. (ST006, DBSTC interview) (ST005, DBSTC interview)

Though the participants were really appreciated the workshop, they suggested the way to improve the NOS workshop by adding more interactive activities in the workshop.

> If you tell me for suggestions, then I should tell that the workshop itself is excellent already, but we could be ready for it and should give more time for it so that you might have more time to show and explain more things to us. After all I've learnt many things today that I knew in another way, so I appreciate and wish you good luck. (ST005, DBSTC interview)

Finally, the participants pointed out the effectiveness and importance of the workshop in helping the participants develop more informed conceptions of NOS.

> If you can go to all of the schools and do this workshop then I think the science teachers will benefitted (ST006, DBSTC interview),It might be easier for all the teachers to get together in some central place than going to them one by one and explain them this way will be more beneficial and fruitful for changing the wrong concept about science and you might get better result (ST011, DBSTC interview)

CHAPTER V
DICUSSION

5.1 Science Teachers' Conceptions of NOS

This study exposed the very similarity of the Bangladeshi science teachers' conceptions of NOS with other science teachers around the world particularly in Southeast Asia such as Thailand (Bell et al., 2000; 2009; Dogan & Abd-El-Khalick, 2008; Haider, 1999; Sarkar, 2010; Shiang et al., 2007). The findings might be attributed to traditional learning and teaching method, as usual classroom practice, typical textbooks, old formed curricula (Buaraphan, 2010) ,the regular educational systems (Haider, 1999) as well cultural influence (Dogan & Abd-El-Khalick, 2008) among the regions

The most common uninformed conceptions of the Bangladeshi science teachers, revealed by this study are described as bellow:

According to most of the teachers, "laws are mature theories fables" (Abd-El-Khalick et al., 1998) which refer that, they are holding 'uncertain' conceptions of hypotheses theory and law relationships aspect. To them, hypotheses are the pre-step of theory, the reason behind the misconceptions is that: The entities are un-cleared to them; as a result they are unable to distinguish the metamorphoses among the terminologies.

In reality, the theories are the comprehensive explanation of the observable phenomena, where laws are the proclamation of those observable phenomenon Even though theories and laws are identically different in science and have different role as well, the participants cannot realize that. The participants fail to differentiate theories and laws, even though these are identically dissimilar and both laws and theories have diverse role in science as well. They conceive that, theories are experimentally established facts and laws are confirmed theories having furthermost number of evidences and supports. In addition, laws are more likely universal truth and can never be changed. These conceptions triggered them to loudening the idea of universal step-wise scientific method (Dogan & Abd-El-Khalick, 2008; Haider, 1999), and theories become law by accumulation and addition of supportive evidences (Bell et al., 2000; McComas, 1998). To be precise, 'hypotheses are developed to become theory only', 'scientific theories are less secured than scientific laws', and 'scientific theories can be developed to scientific laws'. This findings are enormously persistent with other related researches steered on both in pre-service and in-service science teachers (Buaraphan, 2010, 2011) in Asia Pacific context (Buaraphan & Sung-ong, 2009; Sarkar, 2010) as well as around the world (Dogan & Abd-El-Khalick, 2008; Haider, 1999).

According to many participants, scientific knowledge is accumulated with the successive addition of previous knowledge (Buaraphan, 2010; McComas, 1998; Haider, 1999) and it is tentative as well (Bell et al., 2000; Buaraphan, 2010. This unconventional notion of NOS leading the participants towards holding the thought of “laws are mature theory fables”. Over half of the participant cleave to unacquainted conceptions about scientific models that is similar to some others associated study as of Buraphan (2011) where the supporter participants believe that the models are made from the real-time observation and experiments, along with the scientific models are copy of reality not a human creation. Alternatively, some of them also doubtful about scientific models and holding the idea that it might be collectively from the scientist’s experience and creative thinking as well as from the real life (Bell et al., 2000; Haider, 1999)

Likewise to others NOS studies, the participants held mixed conceptions of NOS. Less than a half of them come up with informed conception of NOS, but others have uninformed conceptions of NOS and be uncertain about the capability of science and scientific method whether it can response all questions. Some participants believe that “a scientific method is a specific thorough (step-by step) process” and scientists should follow an organized process. Science may not able to handle some exceptions. Science is based on evidence coming from observations and experiments, but there are some phenomena which are beyond prove. So, obviously, science cannot answer all questions. This study revealed the similar image as of some other previous research like Buraphan (2010; 2011), Haider (1999), Murcia and Schibeci (1999) who attributed these to textbook that are taught in the school level as well as the practical experiments that the school level students do as their supplementary course work. Dogan and Abd-El-Khalick (2008) argued that these thinking might be originated from cultural background of the participants.

The traditional learning approaches of science and inadequate of knowledge about the scientists might be one of important reason behind these dissimilar findings regarding scientists' roles and responsibilities in science. (Dogan & Abd-El-Khalick, 2008). Most of the Bangladeshi science teachers holding uninformed conception about scientist that, they (the scientist) rarely use their imagination and creativity. The participants addressed that scientists are generally open minded and indifferent, as these are the important criteria of good scientists (Buaraphan, 2010), moreover, scientists' actions are experiments and evidence based, and as a result, they have little scope to use their own thinking. With this idea,

According to some of the participants, science and technology are interconnected and relied on each other. Science is 'theoretical' and technology is 'practical'. In particular, technology is applied science (Buaraphan & Sung-ong, 2009). Other studies such as, Buaraphan and Sung-ong (2009) and Tairab (2001) also found these unacquainted conceptions, The participants are unable to differentiate between science and technology are indifferent to the(Rubba & Harkness, 1993). Tairab (2001) indicated that, cultural influences might be the reason behind of this misunderstanding and recommended that the function, responsibilities, and tasks of science and technology as well as the interrelatedness among science and technology and its related issues should be clarified

Contrasting to others research studies, the participants restrained uninformed and uncertain conception significantly that, a scientific endeavor is individual endeavor. In fact, there are numerous factors that influence science directly or indirectly. Therefore, scientific endeavor is a social endeavor. On the other hand, several participants perceive science as a social entity that have direct and indirect influences on culture and politics (Buaraphan, 2010; Haider, 1999; Tairab, 2001). Even though, the greater part of the participants chosen that scientific endeavor is as an individual endeavor but over half of the participant confined informed conceptions about interrelationships of science and the socio-political-culture as well as the influence of socio-political-culture on science, which refer that, the participants are not actually decipherable about “scientific endeavor”, or they conceive that, a scientific innovation begin with the hypotheses; various experiments based on the hypotheses helps to accumulate related and supportive evidence, the more the supportive evidence, the more the stronger the hypotheses, after a certain numbers of evidence, the hypotheses can be developed in to a theory, and a final piece of innovation which has a lot of experiments, a numbers of proves and evidence in its life cycle, comes through a long journey where it influenced by society, politics and culture, for this reason, it is crucial to take a serious steps for considering the issue and eliminate this indistinct conception.

5.2 Science Teachers’ Development of NOS Conceptions after the Explicit-Reflective Workshop

The workshop conducted in this study, to some extent, helps the participating science teachers develop more informed conceptions of NOS. However, some NOS conceptions are resistant to change. The participant science teachers were introduced to several activities and demonstration focusing the mentioned aspects of NOS in this study at the beginning of the workshop program.

A large numbers of the teachers retained ‘uncertain’ conceptions of ‘hypotheses’ and ‘theory’ relationships aspect where they think that “laws are mature theories fables” (Foud Abd-El-Khalick et al., 1998). 14 aspects of NOS were clearly explained several activities that were successfully tested and used in different studies previously conducted. The demonstration helped to teach each of the aspect explicitly appropriate for the secondary and higher secondary science teachers “Teaching the Nature of Science” (Lederman & Abd-EL-Khalick). For example: the researcher has used the “Tricky Track” for observation vs. inferences , scientists’ creativity, imaginations as well as tentativeness of science aspect of NOS. “Young or Old” activity was used to describe the subjectivity and the influences of social and cultural context on NOS. Black box activity like "Mysterious Tube" activity used to clarify that scientific knowledge is a part of human imagination, its source, scientific model and hypotheses etc

After the workshop, all of them substituted their uninformed and uncertain conceptions into informed conceptions. The participants had permanently changed as the terms (hypotheses, theories and laws) were clearly explained with texts, figures in the workshop, so to them there is no fixed step-by step process in science moreover, theories and law different which is reflected by their response in item1, item2, Item 3 and 5. Now, scent percent of them belief that scientific knowledge is changeable, science and scientific knowledge can't answer all the questions as well as science and technology are not exactly similar, more interestingly there is rarely any uncertain indication in any of the aspect after the workshop where there were many before the workshop; hence it is indicating that the workshop is fruitful and successful enough to change the teachers concept of NOS.

On the other hand, more than eighty percent of the participants shifted the attitude about the scientist, science as an endeavor as well as socio-political role on science where a few number still stuck on previous thinking. Even though four times of the participants have changed their concept about the source of scientific knowledge after the workshop, few numbers of them still indicated uninformed knowledge. The maximum uninformed aspect found after the workshop was "accumulation of evidence makes scientific knowledge more stable." The reason might be simple that some the participants cannot change their conception instantly as there was an internal conflict between their two decades wrong belief and my new presentation, so it is hard to accept the fact sometime even though it is proven or well explained.

CHAPTER VI
CONCLUSION

6.1 Conclusion

Two main conclusions can be drawn from this study. First, a large number of the Bangladeshi science teachers possess many uninformed conceptions of NOS like others around the world. Second, the explicit-reflective NOS workshop conducted in this study is effective, to some extent, in helping the participating science teachers develop more informed conceptions of NOS. This study leads to many implications for science education in the Bangladeshi context.

The first implication deals with teacher education and professional development. This study shows the current situation about Bangladeshi science teachers' conceptions of NOS. Before participating in the explicit-reflective NOS workshop, most of the science teachers held some misconceptions of NOS. This study suggests that science teacher educators in Bangladesh now must pay more attention to NOS understanding and integrating NOS in their teaching in classrooms. Although the workshop conducted in this study is in a small scale. The teacher training institutes in Bangladesh can play an important role in designing a NOS course to prepare pre-service science teachers who possess adequate understanding of NOS as well as to conduct the explicit-reflective NOS workshop like this study for fostering in-service science teachers' more informed conceptions of NOS. More further studies should be conducted for designing effective approaches suitable for developing the Bangladeshi science teachers' conceptions of NOS.

The second implication is related to science textbooks (NCTB, 1995). Many misconceptions of NOS appeared in many science textbooks must be remedied. For example, the common misconceptions of NOS regarding the universal, step-by-step scientific method (Siddique, 2008). This misconception is revealed by previous studies that there is no specific method for developing scientific knowledge (Abd-El-Khalick, 1998, 2000; Bell, 2000; McComas, 1998; Lederman, 1999).

The third implication deals with the revision of science curriculum in the Bangladeshi context. The objective of teaching about NOS should be explicitly mentioned in the revision of science curriculum in Bangladesh in the future. The clear learning standard, indicators, objectives, and content of NOS learning must be elaborated and make them clear to all science teachers as well as students. Up to this, science teachers and students are expected to hold adequate understanding of NOS. Without such explicit approach, the development of adequate NOS understanding in students is hard to accomplish.

6.2 Limitations

This study may face several limitations. The first limitation deals with time constraint in the teachers' schedule. The teachers participated in this study were very busy with their tight schedules of daily class routines. They must devote their time and energy for this study. In spite of showing interest, some of the teachers could not attend the program because of their heavy teaching load. Moreover, because of the time limitation, the activities in the explicit-reflective NOS workshop could not start and finish on time because some participants were unable to attend. It also leads to the decrease number of the participants. So, time is the most crucial point here.

The second limitation is from the facilities. Even though the workshop was conducted in the auditorium room of the new school, it lacked some essential facilities such as a LCD projector. So, the presentation and demonstration of some figures had to be done via the laptop computer. To cope with this limitation, the researcher provided the handouts and figures on paper rather than on the projector. However, both limitations are important lessons the researcher learned from this study that can be used to improve the next study.

REFERENCES

Abd-El-Khalick, F., Bell, R. L., & Lederman, G. N. (1998). The nature of science and instructional practice: making the unnatural natural. *Science Education, 82*, 417-436.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education, 22*(7), 665-701.

Abd-El-Khalick, F., Lederman, N. G., Bell, R. L., & Schwartc, R. S. (2001). Views of nature of Science Questionnaire (VNOS): Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science. *Paper presented at the Proceedings of the Annual Meeting of the Association for the Education of Teachers in Science, Costa Mesa, CA.*

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*(4), 295-317.

Akindehin, F. (1988). Effect of an instructional package on preservice science teachers' understanding of nature of science and acquisition of science-related attitudes. *Science Education, 72*, 73-82.

American Association for the Advancement of Science. (1993). *Science for all Americans*. New York: Oxford University Press.

Bartholomew, H., Osborne, J., & Ratcliffe, M. (2004). Teaching students "ideas-about-science": Five dimensions of effective practice. *Science Education, 88*, 655-682.

Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (2000). Developing and acting upon one's conception of the nature of science: a follow-up study. *Journal of Research in Science Teaching, 37*(6), 563-581.

Billeh, V. Y., & Hassan, O. E. (1975). Factors affecting teachers gain in understanding the nature of science. *Journal of Research in Science Teaching, 12*, 67-71.

Buaraphan, K. (2009). Preservice and inservice science teachers' responses and reasoning about the nature of science. *Educational Research and Review 4*(11), 561-581.

Buaraphan, K. (2010). Pre-service and In-service Science Teachers' Conceptions of the Nature of Science. *Science Educator, 19*(2), 35-47.

Buaraphan, K. (2011). Pre-service Physics Teachers' Conceptions of Nature of Science. *US-China Education Review, 8*(2), 137-148.

Buaraphan, K., & Sung-ong, S. (2009). Thai Pre-service science teachers' conceptions of the nature of science. *Asia-Pacific Forum on Science Learning and Teaching, 10*(1),1-22

Cakiroglu, J., Dogan, N., Bilican, K., Cavus, S., & Arslan, O. (2009). Influence of in-service teacher education program on science teachers' views of nature of science. *International Journal of Learning, 16*(10), 597-605.

Craven, J. A., Hand, B., & Prain, V. (2002). Assessing explicit and tacit conceptions of the nature of science among preservice elementary teachers. *International Journal of Science Education, 24*(8), 785-802.

Dogan, N., & Abd-El-Khalick, F. (2008). Turkish grade 10 students' and science teachers' conceptions of nature of science: a national study. *Journal of Research in Science Teaching 45*(10), 1083-1112.

Driver, R., Leach, J., Miller, A., & Scott, P. (1996). *Young people images of science*. Pennsylvania: Open University Press.

Gallagher, J. J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science and Education, 75*(1), 121-133.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of ground theory: strategies for qualitative research*. Chicago: Aldine.

Haider, A. (1999). Emirates pre-service and in-service teachers' views about the nature of science. *International Journal of Science Education, 21*(8), 807-822.

Hanuscin, D. L., Lee, M. H., & Akerson, V. L. (2010). Elementary teachers' pedagogical content knowledge for teaching the nature of science. *Science Education, doi: 10.1002/sce.20404*

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education, 29*(11), 1347-1362.

Irez, S., & Cakir, M. (2006). Critical reflective approach to teach the nature of science: a rationale and review of strategies. *Journal of Turkish Science Education, 3*(2), 7-23.

Trumbull, D., Scarano, G., & Bonney, R. (2006). Relations among two teachers' practices and beliefs, conceptualizations of the nature of science, and their implementation of student independent inquiry projects. *International Journal of Science Education, 28*(14), 1717-1750.

Kuchuk, M. (2008). Improving preservice elementary teachers' view of the nature of science using explicit-reflective teaching in a science, technology and society course. *Australian Journal of Teacher Education, 33*(2). *16-40*

Lederman, J. S., & Lederman, N. G. (2004). *Early elementary students' and teacher's understandings of nature of science and scientific inquiry: lessons learned from project ICAN*. Paper presented at the National Association for Research in Science Teaching, Vancouver, British Columbia, April, 2004

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36*(8), 916-929.

Lederman, N. G., Schwartz, R., Abd-El-Khalick, F., & Bell, R. L. (2001). Preservice teachers' understanding and teaching nature of science: An intervention study. *Canadian Journal of Science, Mathematics, and Technology Education, 1*, 135-160.

Lederman, N., & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understanding of the nature of science. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies*. Netherlands: Kluwer Academic Publishers.

McComas, W. F. (1998). The principal elements of the nature of science: Dispelling the myths. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies*. Netherlands: Kluwer Academic Publishers.

McComas, W. F., Almazroa, H., & Clough, M. P. (1998). The nature of science in science education: An introduction. *Science & Education*, *7*, 511-532.

McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The role and character of the nature of science in science education. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies*. Netherlands: Kluwer Academic Publishers.

Miah, M. B. (2001). *Current situations of basic education of Bangladesh*, Publisher: Mymensingh.

Michael, P. (2006). *Teaching the nature of Science to secondary and post-secondary students: questions rather than tenets.* Iowa State University, LA.

Miles, M. B., & Huberman, M. A. (1984). *Qualitative data analysis: A sourcebook of new methods*.

Moss, D. M. (2001). Examining student conceptions of the nature of science. *International Journal of Science Education*, *23*(8), 771-790.

Murcia, K., & Renato schibeci, S. (1999). Primary student teachers' conceptions of the nature of science. *International Journal of Science Education 21*(11), 1123-1140.

National Curriculum and Textbook Board [NCTB]. (1995). Curriculum and syllabus: *Junior secondary level (grades VI-VIII) [in Bengali]*. Dhaka: Ministry of Education, Government of Bangladesh.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Nichols, S. E., Tippins, D., & Wieseman, K. (1997). A toolkit for developing critically reflective science teachers. *Journal of Science Teacher Education*, *8*(2), 77-106.

NSTA. (2003). *Standards for science teacher preparation.* Washington, DC City: National Science Teachers Association.

Palmquist, B. C., & Finley, F. N. (1997). Preservice teachers' views of the nature of science during a post baccalaureate science teaching program. *Journal of Research in Science Teaching*, *34*(6), 595-615.

Rubba, P. A., & Harkness, W. L. (1993). Examination of preservice and in-service secondary science teachers' beliefs about science-techonology-society interactions. *Science Education, 77*(4), 407-431.

Sarkar, M. M. A. (2010). Science teachers' conceptions of nature of science: The case of Bangladesh. *Asia-Pacific Forum on Science Learning and Teaching, 11*(1), *1-17.*

Schwartz, R., & Lederman, N. (2002). "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching*, *39*(3), 205-236.

Shiang, Lederman, & Norman. (2007). Exploring prospective teachers' worldviews and conceptions of nature of science. *International Journal of Science Education, 29*(10), 1281-1307.

Tairab, H. H. (2001). How do pre-service and in-service science teachers view the nature of science and technolgy? *Research in Science and Technological Education*, *19*(2), 235-250.

Tao, P.-K. (2003). Eliciting and developing junior secondary students' understanding of the nature of science through a peer collaboration instruction in science stories. *International Journal of Science Education, 25*(2), 147-171.

APPENDICES

APPENDIX A

LESSON PLAN

Name of Lesson Plan: Hierarchy Notion

Objectives: Teach about

Item 1 Hypotheses are developed to become theories only

Item 2 Scientific theories are less secure than laws

Item 3 Scientific theories can be developed to become laws

Item 4 The scientific method is a fixed step-by-step process

Item 7 Scientific knowledge comes from experiments only

Teaching process:

1. Use attached overheads to explicitly discuss with the participants about the wrong idea related to the hierarchical relationship among scientific hypothesis, theories and laws.

2. Present Figure 3.4 Notion hierarchical relationships of hypothesis, theories and laws

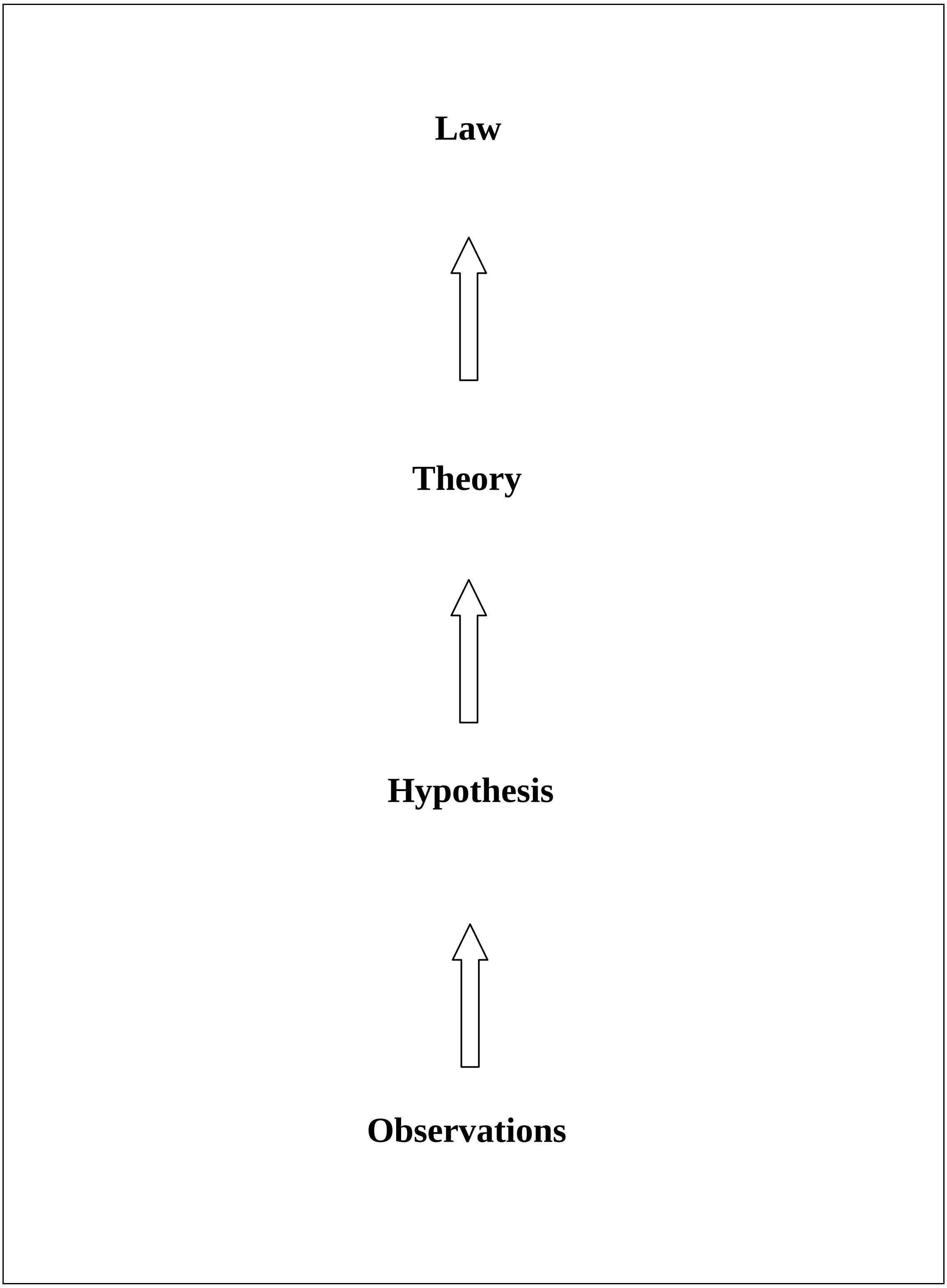

Figure 3.4 Notion hierarchical relationships of hypothesis, theories and laws

3. Convey the correct idea and facts to them with reasoning.

These entities are hierarchically presented in many textbooks and very simply explained that observations develop into hypothesis then hypothesis become theory and finally theory becomes law. It is also described that these hierarchically steps are depends on experiments, supportive evidence and proving. The more evidences can be accumulated, the higher the level of the hierarchy will be achieved. In another word, hypothesis will become theory only and theory will be developed to become law once a plenty of supportive empirical evidences are available to prove or to support it. Thus, it implies that laws are more secured than theories. Figure 3.4 show the notion hierarchical relationship of hypothesis, theories and laws,

This hierarchical relationship as figure 3.4 is wrong for at least two reasons: Theory and law are different kind of knowledge; one cannot develop to another (Mc. Comas, 1996). The theory is an explanation of any observable phenomena. Generally, the theory explains the reasons why things happen. On the other hand, the law describes the relationships among the observable objects or entities and generally, describes what happens. A hypothesis can serve as a pre-step for both theory and law. So, the hypothesis might be developed to theory or law or (even) none. Figure 3.5 describe the definitions of law and theory.

4. Present Figure 3.5 Definitions of law and theory

Scientific law

States, identifies or describes relationships among observable phenomena

Scientific theory

Inferred explanation for observable phenomena

Figure 3.5 Definitions of law and theory

5. Convey the correct idea and facts to them with reasoning.

From the history of science, it is known that "theories become law" is not a valid claim. For example, Boyles' Law describe the relationship and the effect of one into another regarding the 'volume' and the 'pressure' of gas that was proposed by Rober Boyel in 1670. Kinetic Molecular theory that serves as the explanation of Boyles Law was introduced by Rudolph Clawsius and James Clerk Maxwell in 1850. Here the law came first and nearly after a century the related theory came. Geregor Mendel presented his law of inheritance in a paper in 1866, which is interpreted by Chromosomes theory in 1915 by Thomas Morgan and his coworkers (Mix, Farber and King, 1996). Again, the law came here first then related theory. So, the theory is developed to become law is an invalid claim.

6. Present Figure 3.6 the relationship of theories and laws

Scientific Law	Scientific Theory
Boyle's Law	Kinetic Molecular Theory
Mendel's Laws of Inheritance	Chromosome Theory
Newton's law of universal Gravitation and Laws of Motion	?

Figure 3.6 the relationship of theories and laws

7. Convey the correct idea and facts to them with reasoning.

Moreover, there are many laws that are being applied in modern life and the related theory of those laws cannot be introduced yet. For instance, Gravitational law was proposed by Isaac Newton in 1687 but no vital theory for this introduced yet. Newton himself tried to formulate a theory of gravitational law but was unsuccessful. So, still there are some laws that related theories are not introduced yet. Figure 3.6 presents the relationships of theories and law

8. Present Figure 3.7 Alternative View of Relationship among Hypothesis, Law and Theory

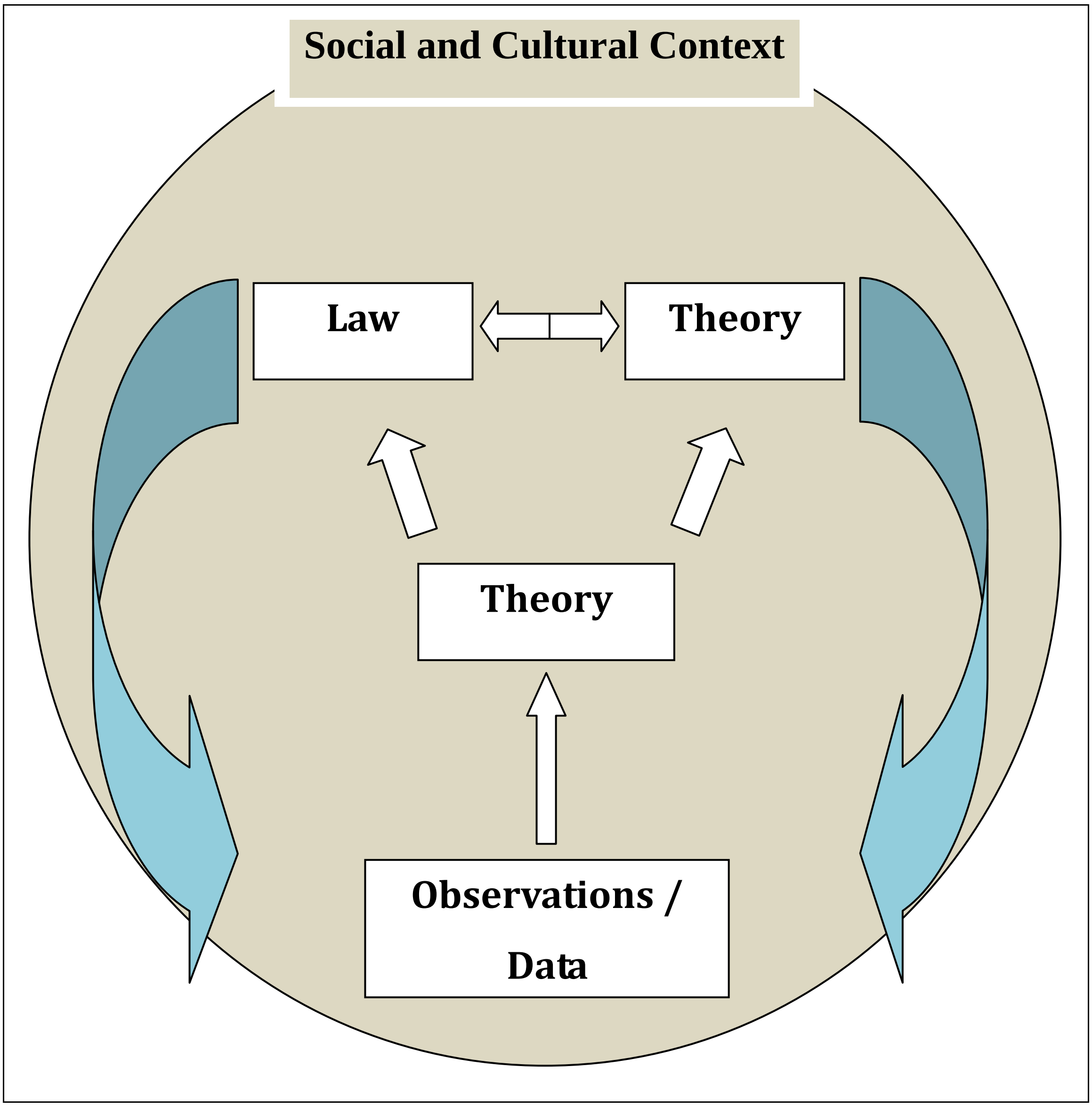

Figure 3.7 Alternative View of Relationship among Hypothesis, Law and Theory

7. Convey the correct idea and facts to them with reasoning.

Figure 3.7 explains the appropriate relationship among scientific hypothesis, theories and laws. Hypothesis is introduced from the observation of natural phenomena. It can be the explanations of the respected phenomena or might the descriptions of the relationships among the observable entities itself. Primary observations are not theory, but it influences further observations, related hypothesis, laws and theories. The whole scientific knowledge is influenced by the socio-cultural context.

Data are collected by depending on many investigations. A hypothesis or a set of hypothesis is formulated after testing and/or modifications. Overcoming this process, a hypothesis can be or cannot be developed to a theory or a law. There is no step-by-step of the scientific method. Influenced by the social and cultural context, it might take from several years to a century even. Thus, the scientific knowledge does not come from the experiments only. Once a law or theory is proposed, it opens the door for further investigations that might or might not introduce any new theory or law. This is the way that history of science is running.

Assessment:

Compare the pre and post test of MOSQ regarding the Following Items

Item 1 Hypotheses are developed to become theories only

Item 2 Scientific theories are less secure than laws

Item 3 Scientific theories can be developed to become laws

Item 4 the scientific method is a fixed step-by-step process

Item 7 Scientific knowledge comes from experiments only

Teaching Material:

- Overhead projector,
- Figures,
- Pictures and
- Presentation handouts.

APPENDIX B
LESSON PLAN

Name of Lesson Plan: Tricky Tracks

Objectives: Teach about

Item 3 Scientific knowledge cannot be changed

Item 9 Scientists do not use creativity and imagination in developing scientific knowledge

Item 10 Scientists are open-minded without any biases

Teaching process:

1. Present Figures 3.5(a) on the overhead;
2. Ask the participants a) "what do you think as you see?"

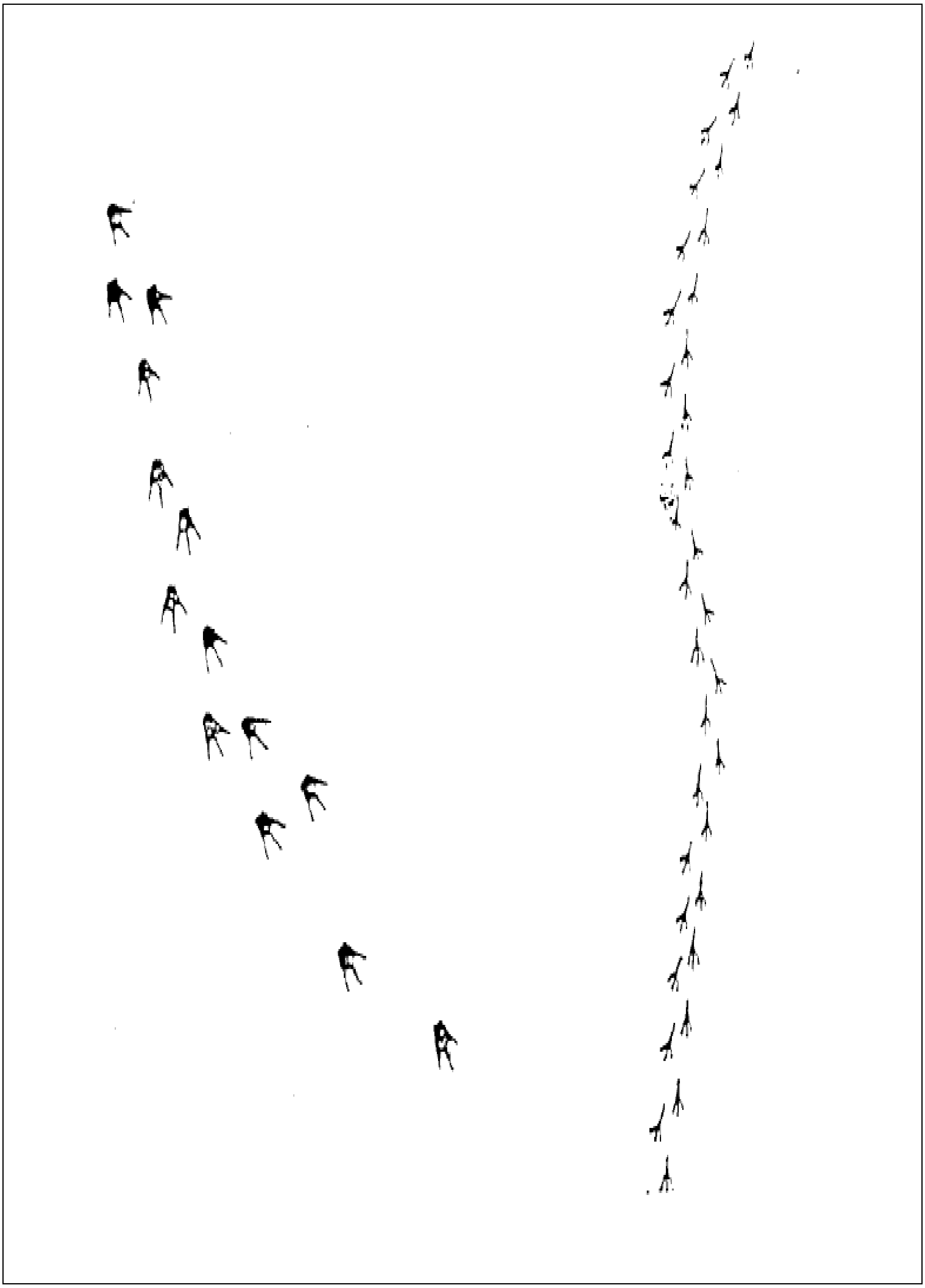

Figure 3.8 Tricky Tracks (a) [Source: Lederman, N., & Abd-El-Khalick, F. (1998)]

3. Note down the answers of the participants one by one then

It is general that most of the participants express their ideas about the tricky tracks that it is the track of some kinds of birds or other animals' footsteps. Once second question was asked “can you see any bird or animal”, the answer is obviously “No”. What are seen on the paper as some black color shapes. For the Figure 3.8(b), it seems that this animals are gone such as birds are flying away. Actually, observations are justified by the observers’ prior knowledge. It is inferences.

4. Present Figures 3.5(b) and
5. Figure 3.5(c) on the overhead,
6. ask the participants

a) "What do you think as you see?"
b) "Can you see any birds or any animals?"

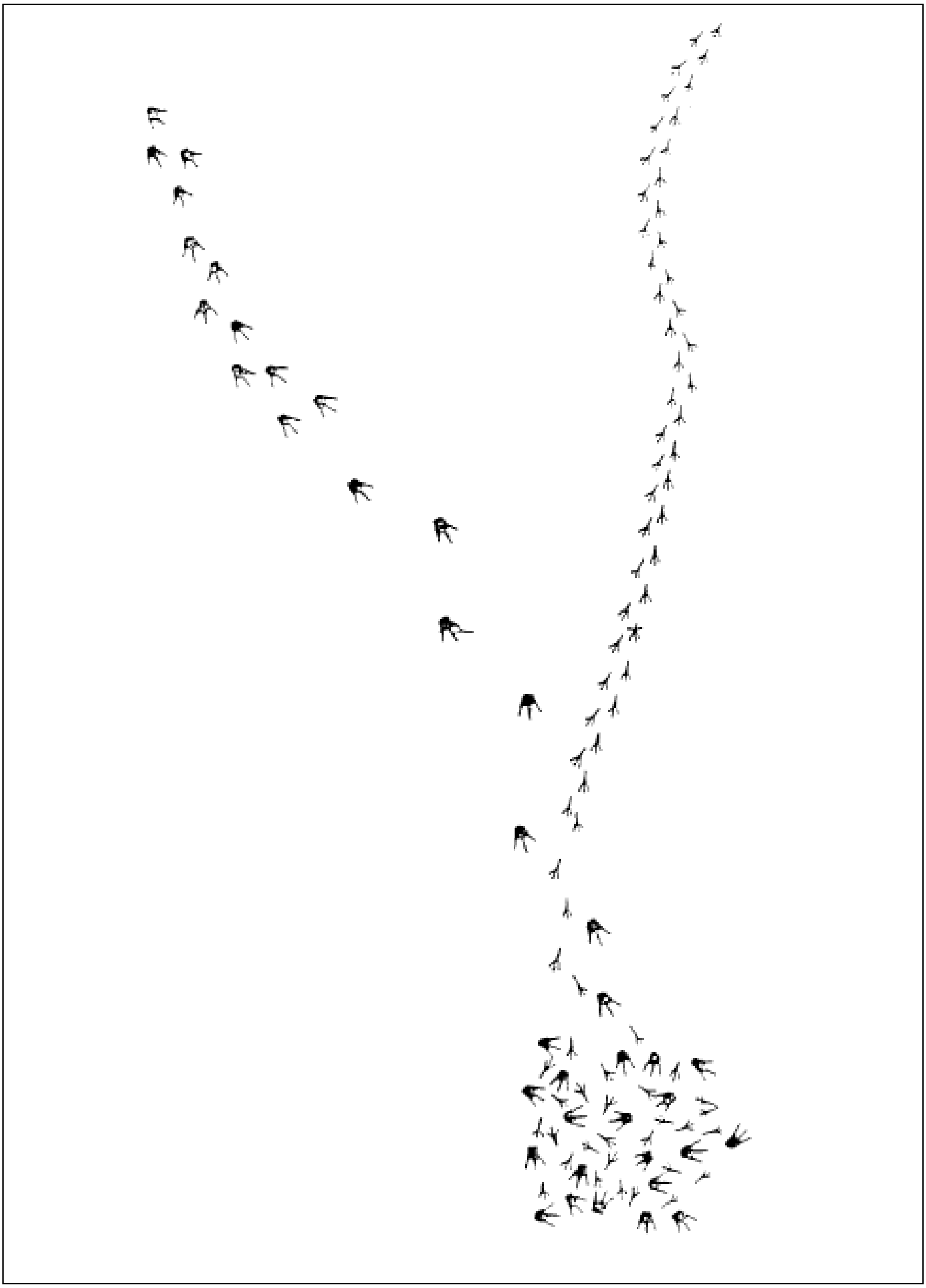

Figure 3.8 Tricky Tracks (b) [Source: Lederman, N., & Abd-El-Khalick, F. (1998)]

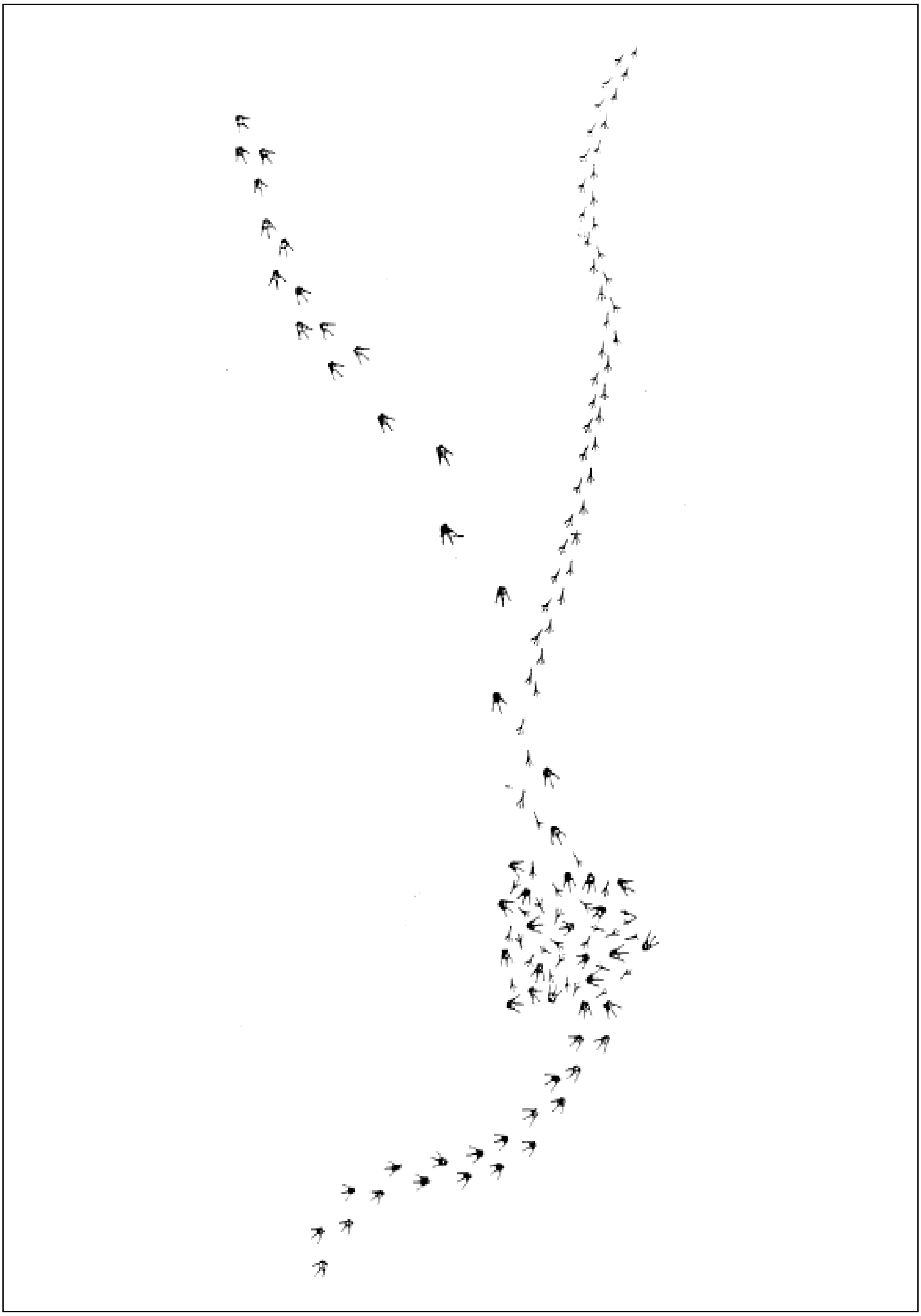

Figure 3.8 Tricky Tracks (c) [Source: Lederman, N., & Abd-El-Khalick, F. (1998)]

1. Note down their reasoning for their justifications or logical guess.

When Figure 3.8(b) is presented and closely observed in more details and in more logically presented, the participants uses their imagination or creativity to explain their inferences with more arguments such as the animal might heading going towards some destination for foods or water and somehow they died over there and eaten by their predators. By observing further more Figure 3.8(c), both types of animals might heading towards same source for same purpose but the weaker is eaten or killed by the stronger and finally the winner group is leaving the spot. These all are inferences and might be possible. And it is possible to come up with different inferences with supporting logical evidences from the same observation.

2. Explicitly discuss with the participants about

a) Observation vs. inferences

b) Scientists' creativity and imaginations

c) Tentativeness of science

Scientists might observe the natural phenomena, collect data, make inference, based collected data, and by all possible consistent data they try to answers their questions. This process might influenced by their creativity and imagination. Their prior knowledge might help them to infer the new situations as it happened to the participants. After that, they might do more experiments and test to gather more sensible supporting data to prove their findings.

So, scientific knowledge is changeable and it depends on socio-cultural context. One who comes up with some phenomena with proven supports and evidence then it might be acceptable in some extent. Scientists are creative and imaginative in their investigations. As human beings, they are not above the influence of the environments, so they might not be always opened minded**.** Even though scientific knowledge emphatically evidence based, it is socio-culturally embedded. Scientists are the part of that and might be biased too.

Assessment:

Compare the pre and post test of MOSQ regarding the following Items

Item 3 Scientific knowledge cannot be changed

Item 9 Scientists do not use creativity and imagination in developing scientific knowledge

Item 10 Scientists are open-minded without any biases

Teaching Material:

- Overhead projector,
- Figures and Pictures and
- Presentations handouts.

APPENDIX C
LESSON PLAN

Name of Lesson Plan: Young or Old

Objectives: Teach about

Item 10 Scientists are open-minded without any biases

Item 14 Society, politics, and culture do not affect the development of scientific knowledge

Teaching process:

1. Present Figures 3.9 on the overhead,
2. Ask the participants a) "what do you think as you see?"

Figure 3.9 Young or old [Source: Lederman, N., & Abd-El-Khalick, F. (1998)]

3. Note down the answers of the participants one by one then

Some participants came up with confident conclusion that the drawing is of an old lady. Some others see it as a young lady looking at the other side. Few argued that this drawing is showing a bird or an animal eating something.

4. Then ask again b) "can you explain your thinking?"

From the explanations, the participants able to argue with their own logic about the face, nose, eye, check, hair, neck of young or old lady. The supporter of bird or other animal even tried to establish their argument by providing logical sign of the drawing they observed.

5. Note down their reasoning for their justifications or logical guess.

All of their arguments were based on their observations, and inferences. They have used their background knowledge with the observed drawing and fond out different picture based on their scientific knowledge, and experience which are accumulated from culture and society as well.

6. Explicitly discuss with the participants about

a) Subjectivity in science

b) Influences of social and cultural contexts on science

This is the way that scientists actually work; they observe the natural phenomena and try to find out the answer of their questions. From the similar observations, different scientists might come up with different findings. All of them might have their own evidences to support their arguments. They might use their background knowledge, skills and experiences. Ones' arguments might or might not acceptable by others, because of their lack of open mind ness and social, cultural, and politically embedded scientific knowledge.

Assessment:

Compare the pre and post test of MOSQ regarding the following Items

Item 10 Scientists are open-minded without any biases

Item 14 Society, politics, and culture do not affect the development of scientific knowledge

Teaching Material:

- Overhead projector,
- Figures and Pictures and
- Presentations handouts.

APPENDIX D
LESSON PLAN

Name of Lesson Plan: Mysterious Tube or "Black Box"

Objectives: Teach about

Item 9 A scientific model (e.g., the atomic model) expresses a copy of reality

Item 10 Scientists do not use creativity and imagination in developing scientific knowledge

Teaching process:

1. Present handmade (from rolled tissue holder) model of "Black Box or Mysterious Tube"

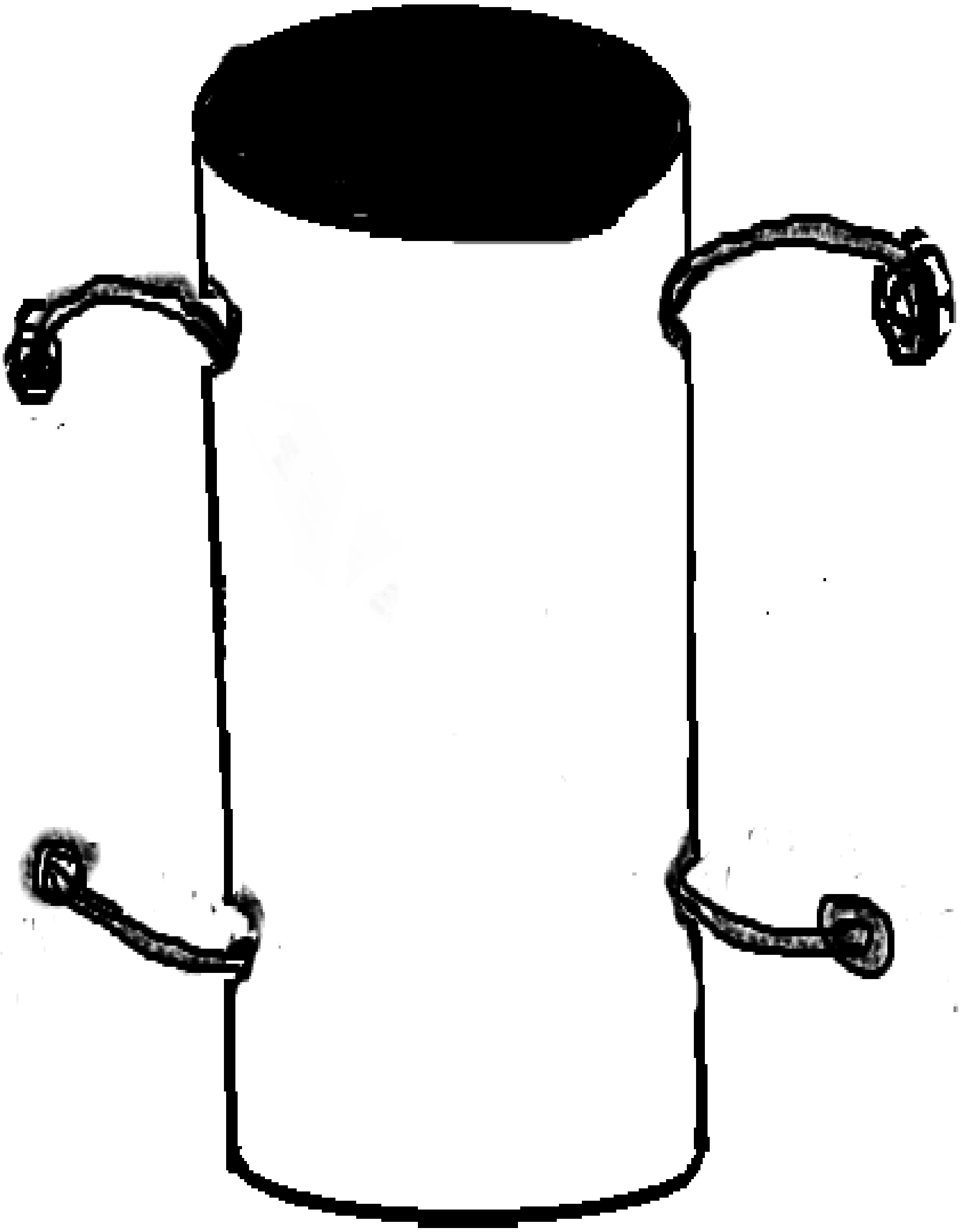

Figure 3.10 Mysterious Tube or “Black Box” (a) outside

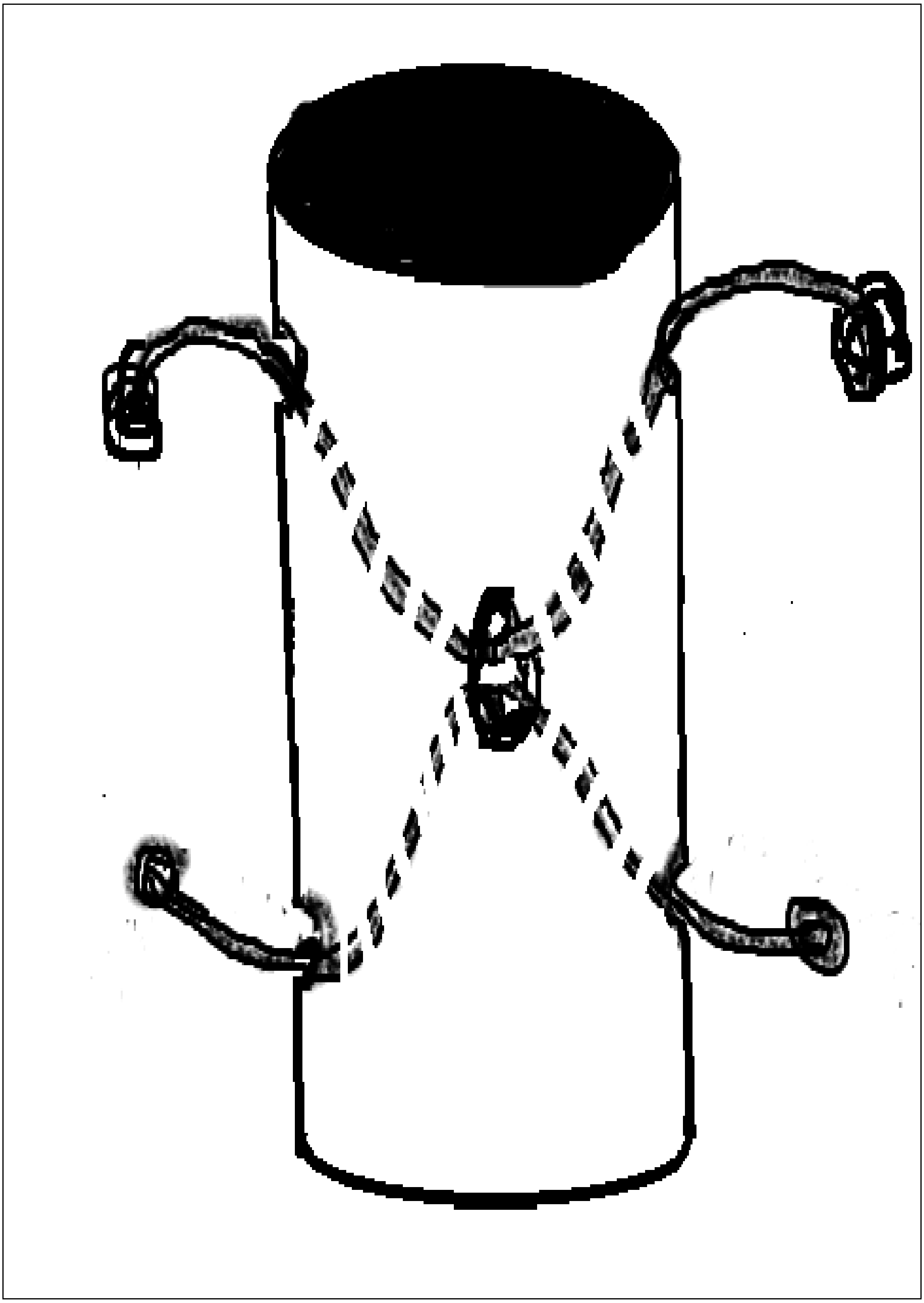

Figure 3.10 Mysterious Tube or “Black Box” (b) Inside

2. and use Figure 3.10 (a) and 3.10 (b) on the overhead,
3. and ask the participants
4. "What do you think as you see?”
5. Note down the answers of the participants one by one.

Participants inferred as they see the mysterious tube or black box. Some to them expressed their idea such as, the pieces of two ropes are horizontally same piece and vertically separated two pieces of rope or it’s two pieces are vertically separated, or the ropes are attached together crosswise inside.

6. Then ask again "Can you explain your thinking?"
7. Note down their reasoning for their justifications or logical guess.

The real picture of inside is unknown and the participants are trying to imagine and pull the one side of the rope and observe what happens to the other side of the rope. As the opposite sided rope is responding or becoming shorter, so they concluding that they are attached together inside the tube.

8. Explicitly discuss with the participants about
   a) The scientists' work and scientific model.
   b) scientific knowledge is a part of human imagination and creativity
   c) scientific model
   d) Scientific hypotheses, theories and laws

Scientists’ work is very much similar to this. In order to come up with or discover a new phenomenon, scientists observer all passible and available points, Collect data, make an inference, propose a hypothesis, to go further according to the hypothesis, do experiments and tastings, come up with rough conclusion and then create a scientific model using their imaginations to explain their investigations and phenomena, try to make sensible logical answers with evidence of the unknown phenomena.

Assessment:

Compare the pre and post test of MOSQ regarding the following Items

Item 9 A scientific model (e.g., the atomic model) expresses a copy of reality

Item 10 Scientists do not use creativity and imagination in developing scientific knowledge

Teaching Material:

- Handmade model of mysterious tube,
- Overhead projector,
- Figures and Pictures and
- Presentations handouts.

APPENDIX E
LESSON PLAN

Name of Lesson Plan: Mysterious cube or “Black Box”

Objectives: Teach about

Item 10 Scientists do not use creativity and imagination in developing scientific knowledge

Teaching process:

1. Present handmade (from folded paper Cube) model of “Black Box or Mysterious Cube” and

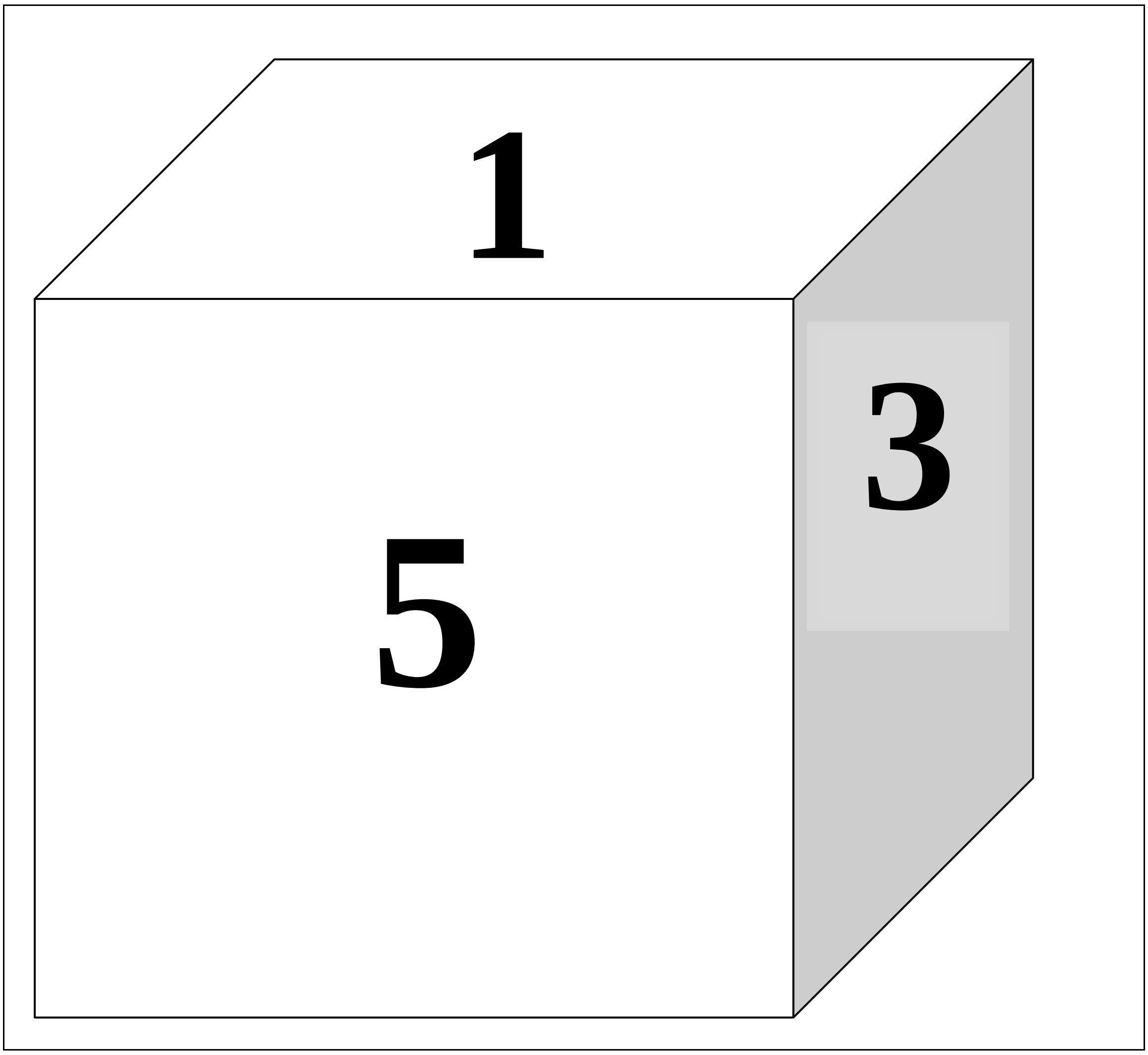

Figure 3.10 model of “Black Box or Mysterious Cube

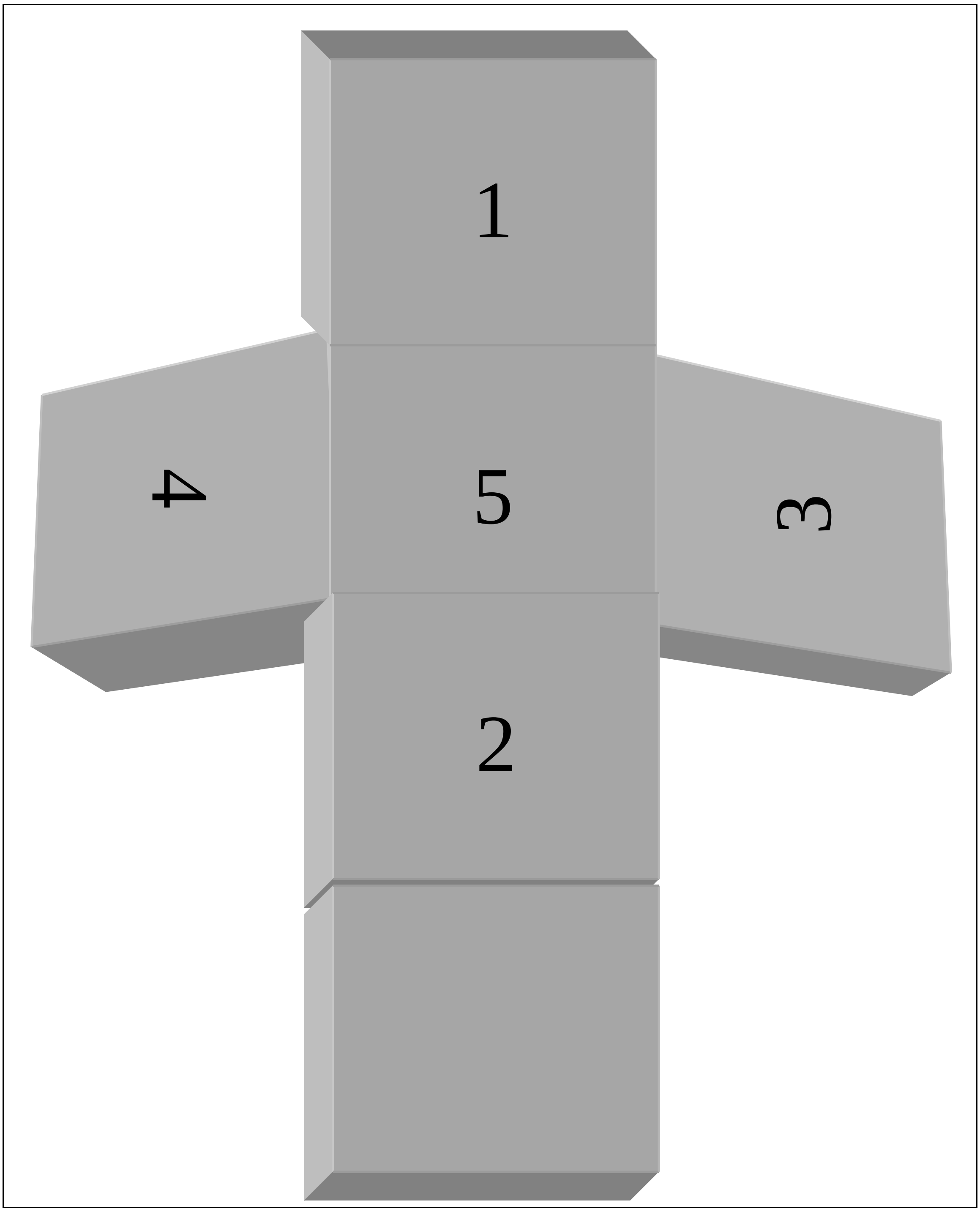

Figure 3.10 Myterioius Cube (a)

2. Use Figure 3.10 (a) on the overhead, and ask the participants
3. "What do you think about the unseen number in the cube?”
4. Note down the answers of the participants one by one.,

By observing the cube, all of the participants inferred that, the unseen number might be ‘6’. Five sides of the cube is filled with the five numbers 1, 2, 3, 4, and 5. There are six sides in a cube.

5. Then ask again "Can you explain your thinking?"
6. Note down their reasoning for their justifications or logical guess.

If we see the pattern, then it easily inferred that the next number should be ‘6’. Moreover the five sides of the cube is known already, so the unknown side is obvious to be the next number of the pattern and that is number ‘6’.

7. Use Figure 3.10 (b) on the overhead, and

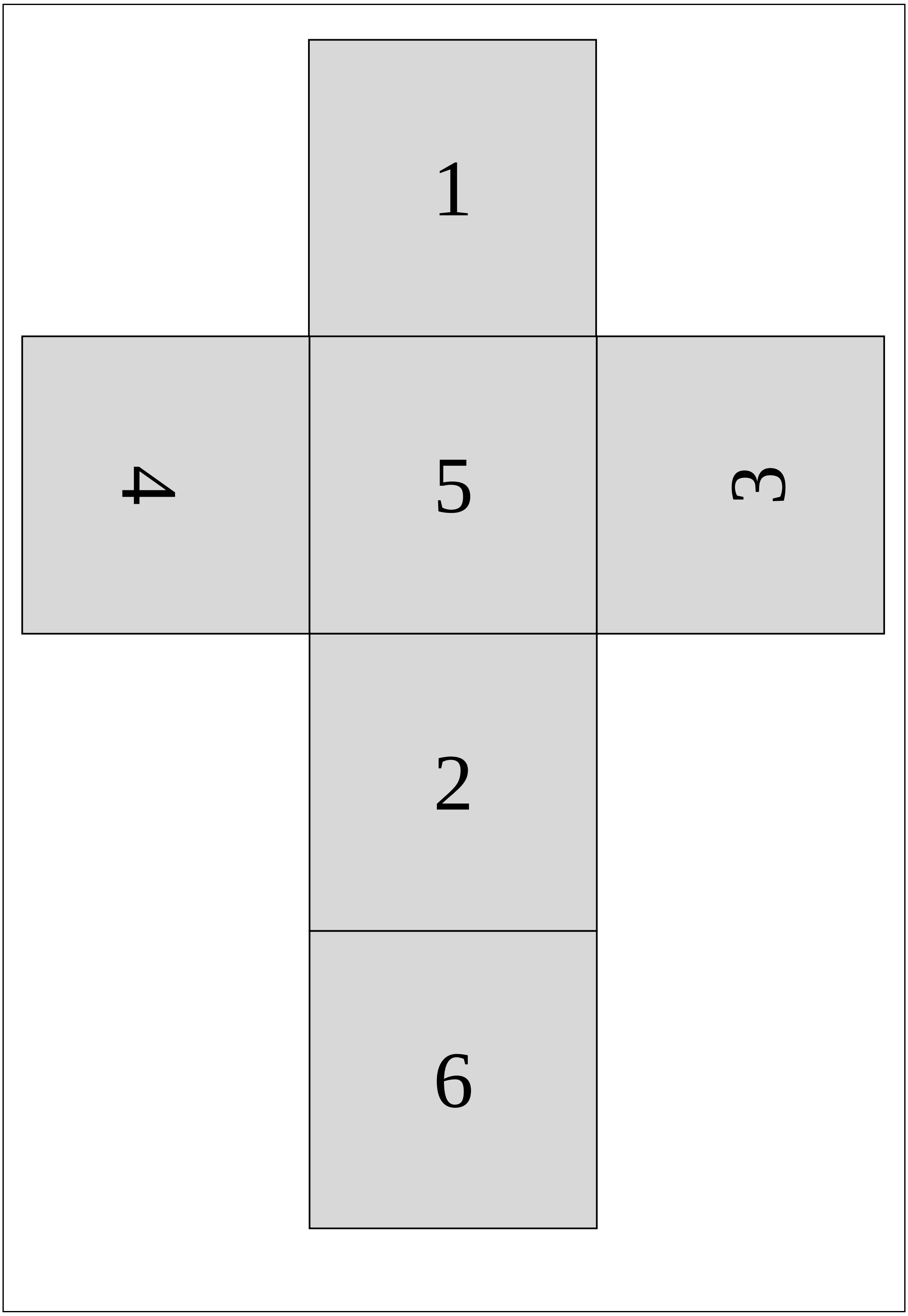

Figure 3.10 Myterioius Cube (b)

8. Explicitly discuss with the participants about
   a. The scientists' work.
   b. scientific knowledge is a part of human imagination and creativity
   c. scientific hypotheses, theories and laws

Scientists’ works can be referred as this mysterious cube. They observe the natural phenomena, collect the data, look for the pattern, infer the unknown data, and support the evidence for their proposed answers. Propose a hypothesis, do more experiments, testing and collect more data and finally conclude scientifically from their findings and results. Imaginations, creativity and their background knowledge lead them to their observations, investigations, scientific inquiry, hypothesis constructing, and scientific discovering process. These are the fundamental systematic process that a scientist comes over to reveal the unknown natural phenomena.

So, the ‘black box’ or ‘mysterious cube’ activity refers that scientific knowledge is influenced by human inference, imaginations and creativity. Scientific knowledge depends on empirical, and inherited from observation, experiments and evidence. Scientific models are constructed and used to describe and explain natural phenomena.

Assessment:

Compare the pre and post test of MOSQ regarding the following Item

Item 10 Scientists do not use creativity and imagination in developing scientific knowledge

Teaching Material:

- Handmade model of mysterious cube,
- Overhead projector,
- Figures and Pictures and
- Presentations handouts.

BIOGRAPHY

NAME	Md. Ziaul Abedin Forhad
DATE OF BIRTH	22 March 1981
PLACE OF BIRTH	Dhaka, Bangladesh
INSTITUTIONS ATTENDED	Assumption University, 2001-2007 Bachelor of Science (Information Technology) Mahidol University, 2008-2013 Doctor of Philosophy (Science and Technology Education)
HOME ADDRESS	House No: 520/666, Auchpara, Avijan-108, Tongi Gazipur, Dhaka, Bangladesh Tel.+ 88-02-9801408 E-mail : zforhad@gmail.com
EMPLOYMENT ADDRESS	Administration, Crescent International School , Bangkok 72, Soi Sri Bumphen ,Rama 4 Thungmahamek, Sathon , Bangkok, 10120, Tel. (66) 02 679 8777 Fax: (66) 02 679 8817
PUBLICATION / PRESENTATION	The Development of Bangladeshi Science Teachers' Conceptions of Nature of Science